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**SATURN S-II
QUALITY ASSURANCE TECHNIQUES**

NONDESTRUCTIVE TESTING PROCESSES

Volume I - Requirements and Procedures

30 October 1970

Prepared by

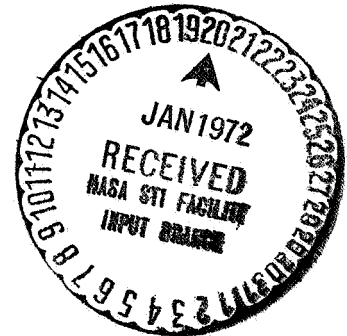
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Space Division
North American Rockwell

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ABSTRACT
<p>THIS VOLUME IS SUBMITTED TO NASA AS PART OF THE EFFORT BY NORTH AMERICAN ROCKWELL'S SPACE DIVISION TO DOCUMENT SPECIAL SKILLS DEVELOPED DURING THE SATURN S-II PROGRAM. THIS EFFORT PROVIDES DOCUMENTS WHICH WILL ENABLE QUALIFIED PERSONNEL UNFAMILIAR WITH THE PROGRAM TO CARRY OUT EFFICIENT OPERATIONS IN FUTURE S-II PRODUCTION.</p>



FOREWORD

This volume is submitted to the National Aeronautics and Space Administration as part of the effort by North American Rockwell Corporation's Space Division to document special skills developed during the Saturn S-II Program. This effort, performed under Contract NAS7-200, provides documents which will enable qualified personnel unfamiliar with the program to carry out efficient operations in future S-II production.

This is Volume I of S-II Nondestructive Testing Processes, which emphasizes the inspection aspects of nondestructive testing. The complete set includes:

S-II Nondestructive Testing Processes (SD 70-556)

- Vol. I - Requirements and Procedures
- Vol. II - Radiographic References

S-II Critical Process Control (SD 70-557)

- Vol. I - Adhesive Bonding
- Vol. II - Foam Insulation
- Vol. III - Primers and Coatings
- Vol. IV - Foil Seals and Potting
- Vol. V - Contamination
- Vol. VI - Chemical Processing
- Vol. VII - Metallic Materials
- Vol. VIII - Raw Material Control



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INTRODUCTION AND SUMMARY

This volume outlines the methods and procedures used to perform nondestructive testing (NDT) inspections of the Saturn S-II liquid hydrogen (LH₂) and liquid oxygen (LO₂) tank weldments and selected structures during fabrication and after proof-testing. The radiographic, fluorescent-penetrant, and ultrasonic inspection processes described herein are the result of progressive development and refinement to achieve optimum results.

A brief description of the structural/weldment nondestructive testing inspection requirements are as outlined in the following paragraphs.

All structural welds joining the assemblies of the LH₂ and LO₂ tank primary structures are inspected using radiographic and penetrant-inspection methods during the initial fabrication and assembly. Structures joined by welding from opposing sides receive an additional inspection using an ultrasonic shear wave method.

After proof-testing of the completed assemblies, all the major structural welds are reinspected using radiographic and penetrant-inspection methods. In addition to the normal inspection, all anomalies revealed are compared and closely analyzed during these post-test inspections for possible propagation. The post-test inspections are made after the most significant proof-testing. For example, bulkheads inspected after a hydrostatic test are not reinspected after a subsequent pneumatic test if the loads imposed are less than those imposed during the hydrostatic test. All post-test inspection requirements are outlined in this section.

The common bulkhead is a sandwich-type assembly formed by bonding two bulkhead facing sheets to a honeycomb core center. The two facing sheets are referred to as the forward facing sheet and aft facing sheet prior to their joining. The bonding integrity of the common bulkhead is inspected on a special tool using an ultrasonic squirter-type system designed specifically for this purpose. A "C" scan recording of the inspection is made to facilitate the inspection process and to obtain a permanent record of the completed inspection.

A debris barrier is installed at X_B 866 location between the forward LH₂ bulkhead and the forward skirt assembly to prevent foreign objects from becoming wedged in the "V" cavity and causing a failure of the bulkhead during later testing or during flight. To assure that no foreign objects are

in the cavity (the area cannot be visually examined) before installation of the barrier, the area is examined by X-ray inspection. To assure that objects were not dropped into the cavity during the barrier installation, the area is again X-ray inspected after final installation.

The general locations of the subassemblies discussed herein and their location in relation to the completed S-II launch vehicle are illustrated in Figure 1. These subassemblies and their inspection requirements are discussed on the following pages of this section.

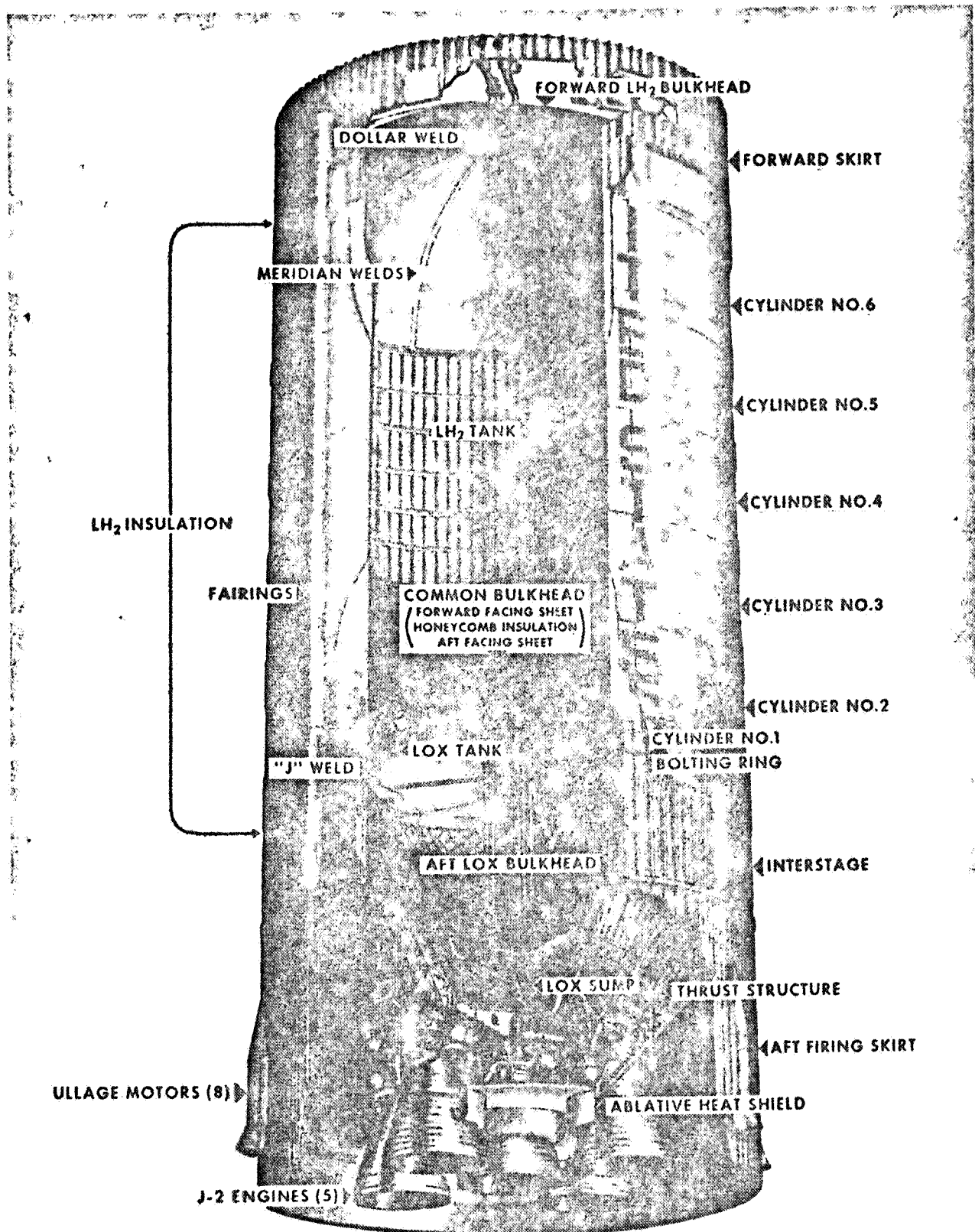
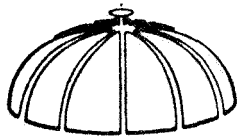


Figure 1. Complete Stage Assembly, Saturn S-II

BULKHEAD WELDS

Bulkheads are constructed from 12 gore sections and one dollar section joined by machine-fusion welding. The inspection requirements are as follows:

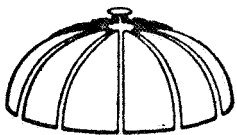


LH₂ Forward Bulkhead

After initial fabrication: X-ray and penetrant-inspect all welds.

After hydrostatic test: Penetrant-inspect all welds (both surfaces). X-ray inspect all meridian welds from equatorial net trim, line up 172 inches.

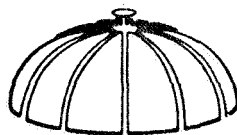
After pneumatic test: Penetrant-inspect all welds on inboard surface only. X-ray inspect the dollar weld and each meridian weld from 172 inches up from the equatorial net trim line to the dollar weld.



Forward Facing Sheet

After initial fabrication: X-ray and penetrant-inspect all welds.

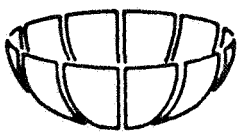
After pneumatic test: Penetrant-inspect dollar weld and all meridian welds from the dollar weld down 60 inches (outboard surface only).



Aft Facing Sheet

After initial fabrication: X-ray and penetrant-inspect all welds.

After hydrostatic test: X-ray and penetrant-inspect all welds.



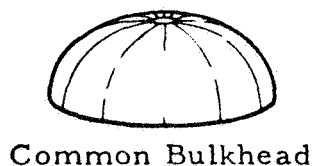
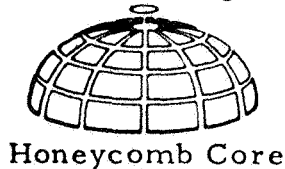
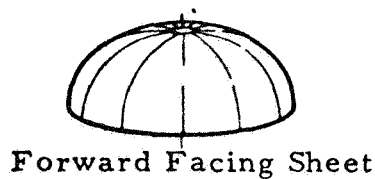
Aft LO₂ Bulkhead

After initial fabrication: X-ray and penetrant-inspect all welds, ultrasonic-inspect dollar weld.

After hydrostatic test: X-ray and penetrant-inspect all welds, ultrasonic-inspect dollar weld.



COMMON BULKHEAD ASSEMBLY



The common bulkhead is a sandwich assembly consisting of the forward facing sheet, aft facing sheet, and a honeycomb core center. These assemblies are joined in two separate operations by adhesive bonding.

After layup and bonding of the honeycomb core to the aft facing sheet, random areas are inspected using the pulse echo contact method.

Immediately prior to the forward facing sheet layup, the locations of all core splices and other internal structural information are recorded to facilitate interpretation of the subsequent complete ultrasonic inspection after assembly is completed.

The completed bulkhead assembly is inspected for bonding integrity using an ultrasonic squirter through transmission and pulse echo system specifically designed for this purpose.

VERTICAL WELDS

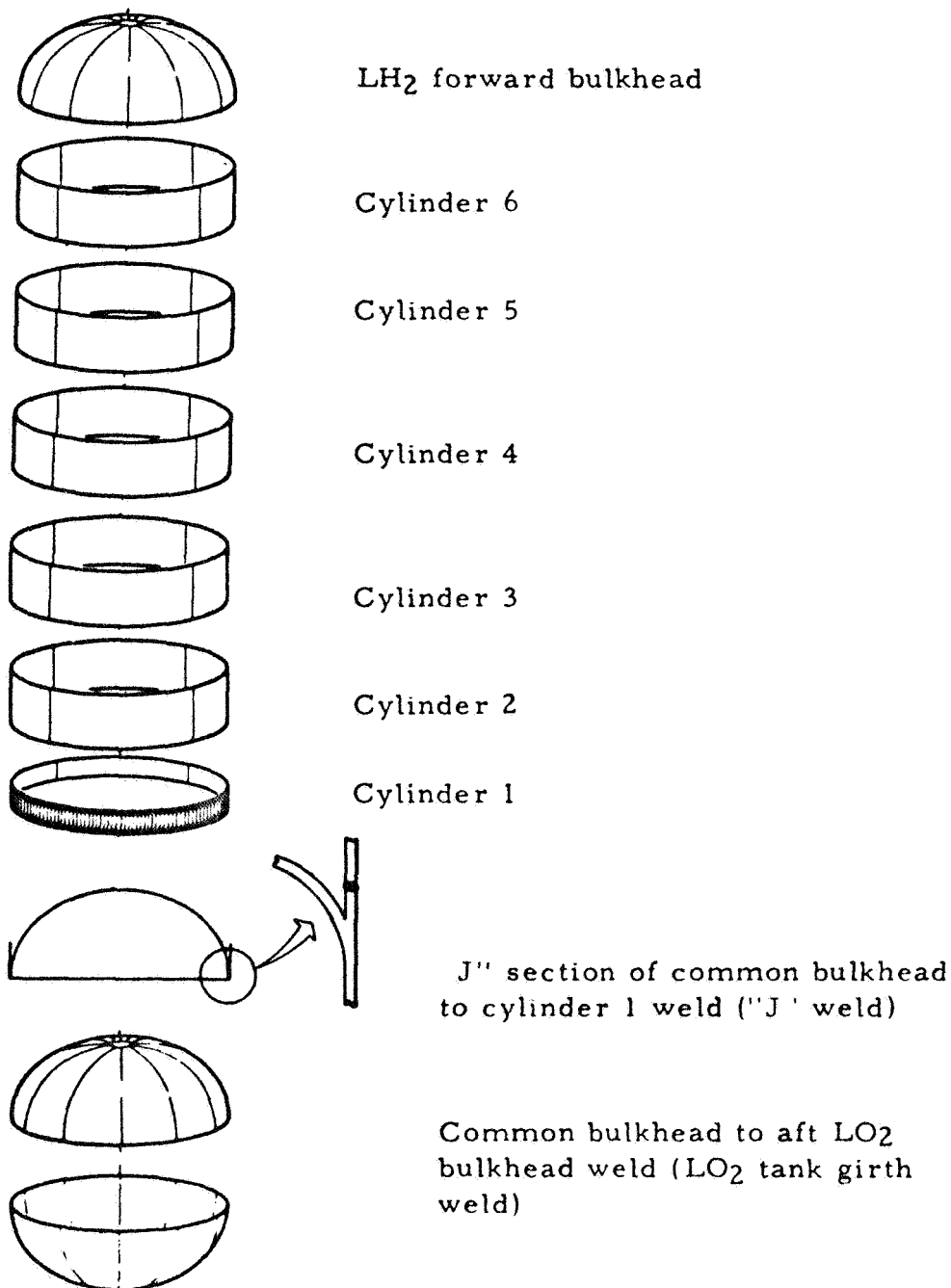
Cylinder assemblies are fabricated by joining four quarter panels by machine-fusion welding. These vertical (splice) welds are X-ray and fluorescent-penetrant inspected 100 percent after initial fabrication and again after the pneumatic testing of the LH₂ tank assembly.





CIRCUMFERENTIAL WELDS

All completed cylinders and bulkheads are joined by machine-fusion welding. All circumferential welds are X-ray and fluorescent-penetrant inspected after initial fabrication and again after pneumatic testing except for the "J" section weld. The "J" section weld is inspected after initial fabrication only and is not penetrant-inspected on the inboard surface because of inaccessibility.





MISCELLANEOUS WELDS

The following weldments join detail parts to major assemblies and are initially X-ray and penetrant inspected at the supplier's facilities before shipment to the Seal Beach facility. These welds are included because of reinspection performed after pneumatic testing of the LH₂ tank.

LH₂ tank fuel outlet subassembly
to quarter panel butt welds

Penetrant-inspect (both
surfaces). X-ray inspect
from position 8 o'clock to
4 o'clock only. (Four o'clock
to eight o'clock is not
accessible)

LH₂ tank fill and drain ring
butt weld

X-ray inspect and penetrant-
inspect both surfaces

Engine cutoff (ECO) and
recirculation pump castellated
bosses

Penetrant-inspect complete



1.0 RADIOGRAPHIC INSPECTION PROCESSES

1.1 RADIATION SAFETY PROCEDURES

This section defines the procedures used to operate X-ray machines safely and efficiently at North American Rockwell's Space Division.

The procedures are applicable to all persons who operate or assist in the operation of X-ray machines. All such operations are performed in accordance with the safety provisions and requirements defined in the following material

1. Industrial Safety Operations Standards - Book 2, Part 1, Section IV
2. State of California Administrative Code, Title 17
3. Radiological Health Handbook - U.S. Department of Health, Education, and Welfare Public Health Service
4. Nondestructive Testing Handbook, Volume I
5. California Radioactive Materials License 0021-70
6. NDT Desk Instruction Number 10 - Standard Radiation Safety Procedures for the Seal Beach Facility Using Conventional X-ray Producing Machines

Deviations from the procedures described in Section 1.1 may require prior approval of the Space Division Radiation Safety Officer and responsible supervision, Nondestructive Testing section, S-II Quality Assurance.

GENERAL PROCEDURES

The procedures discussed in the following paragraphs are important for safe operation of X-ray equipment, and deviations are not permitted except in accordance with the provisions noted herein.

The presence of supervision from the Nondestructive Testing (NDT) section, S-II Quality Assurance (QA), or a qualified representative of the NR SD Radiation Safety Office (RSO) is required for any radiographic exposure that cannot be accomplished in accordance with these procedures. In addition, a radiation monitoring record (Figure 1-1), used for all X-ray



SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION
RADIATION MONITORING LOG

18261

DATE _____ FACILITY _____ BLDG NO. _____ DEPARTMENT NO. _____

SHIFT _____ GRID LOCATION _____ PROCEDURE OR TOOL NO. _____

Type of Radiation X-RAY: KV _____ MA _____
ISOTOPE: Nomenclature _____ Activity _____ (Curies)

RADIATION PRODUCING DEVICE: MODEL _____ SERIAL NO. _____

SURVEY INSTRUMENT MAKE: _____ MODEL _____ SERIAL NO. _____

USER'S NAME 1. _____ 2. _____ 3. _____

DOSIMETER NO. 1. _____ 2. _____ 3. _____

FILM BADGE NO. 1. _____ 2. _____ 3. _____

(Note: Technician or Radiographer in Charge Use Line 1.)

Background Surveys
as required
Do Not Subtract

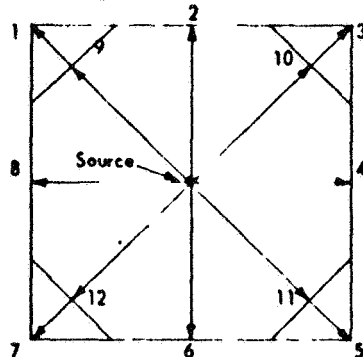
Time				
Mr/Hr				

(RECORD AT TWO-HOUR INTERVALS)

RADIATION AREAS IN FEET

INVERSE SQUARE LAW

$$\frac{I_1}{I_2} = \frac{(D_2)^2}{(D_1)^2}$$



Type of Shielding

Used: _____

Thickness of Shielding

Used: _____

UNRESTRICTED

RESTRICTED

HIGH RADIATION

SOURCE

POINT NO.	TIME OF DAY	DURATION TIME	Mr/Hr	MONITOR INITIAL

ISOTOPES ONLY
RECORD OF PHYSICAL RADIATION SURVEY OF
ISOTOPE IN SHIELDED STORAGE POSITION

Time of Day _____

Mr/Hr at 1 Meter _____

Mr/Hr at Surface _____

MONITOR: _____

Figure 1-1. Radiation Monitoring Log

operations, will be signed by NDT supervision and/or a qualified representative of the RSO indicating his authorization to perform a non-standard procedure. Reasons for the specific deviation(s) will be listed on the back of the applicable form.

All persons who operate or visit areas where exposure to X-ray is possible will have a radiation exposure film badge and a self-reading pocket dosimeter which shows measurement values in milliroentgens (mr). Each pocket dosimeter, with a range of 0 to 200 mr, is read at the start and end of each work shift to measure the daily amount of radiation exposure to which each employee has been subjected.

Each film badge is exchanged and processed through the RSO on the 15th day of each month or immediately following a radiation incident to determine the total monthly amount of radiation exposure.

PROCEDURE

X-ray Operations Within Enclosed, Lead-Lined Rooms

A lead-lined room constitutes a permanent enclosure that is equipped with automatic shutoff devices for X-ray machines if entry to the area is attempted while radiographic operations are in progress. The minimum requirements for qualification of personnel to operate X-ray equipment within lead-lined rooms are included in the following listing. (Reference NR SD Industrial Safety Operations Standards, State of California Administrative Code, Title 17, and NR SD NDT Desk Instruction Number 10)

1. Qualification of each employee by a certified NDT supervisor is required.
2. Successful completion of a radiation physical examination and a preliminary briefing by the Radiation Safety Officer (or his designated representative) is required before operating X-ray equipment.
3. Operators will receive a minimum of two hours on-the-job training by a certified radiographer for each X-ray machine to be used.
4. Operators will demonstrate a satisfactory level of understanding and competence or proficiency in the use of X-ray equipment prior to operating machines without surveillance.
5. Operating personnel will wear a film badge plus appropriate dosimeter at all times while performing their duties.



6. In the event any actual or purported radiation accident occurs, Nondestructive Testing supervision will be notified immediately, and the applicable portions of Industrial Safety Operations Standards will be implemented.

Standard Field-Type X-Ray Operations Performed Without Enclosed, Lead-Lined Rooms

Each radiographic technician who operates X-ray machines will possess a valid certification issued by the Training department and approved by the Industrial Safety department. Noncertified personnel may assist in operations involving movement of equipment or act as "guards" to secure large radiation areas, provided that safety is not impaired; all such personnel will take directions from the senior certified radiographer assigned to the task and present in the area.

Safety-approved types of collimators are used for X-ray exposures not performed in lead-lined enclosures. Tasks performed with collimators at distances in excess of 2 inches (i.e., from the end of the collimator to the part) will require written approval of NDT supervision or the RSO before proceeding if the condition is not shown in the specific sequences shown in Figures 1-2 through 1-18. (See end of section.)

For all normal radiographic exposures, lead (or lead-impregnated vinyl stripping) backup shielding is positioned to attenuate all primary and secondary scatter radiation to a maximum level of 2 mr per hour when measured at a distance of 3 feet from the object. Shielding is placed as close as possible to the object being X-rayed. An exception is allowed for in-board areas of S-II stage circumferential cylinder welds provided that personnel are evacuated and access to the inside area is completely blocked or guarded. Placing shielding more than 2 inches from the object requires prior approval of NDT supervision or the RSO if not shown in the sequences in Figures 1-3 through 1-19.

The standard practice of limiting radiation to 2 mr per hour when measured at a distance of 3 feet from the object is used as a guide only. Whenever feasible, all radiation exposures are reduced to a lesser value (0.5 mr per hour or less when measured at a distance of 3 feet from the object). Nondestructive Testing supervision determines when feasible conditions exist.

Before authorizing an X-ray machine to be energized, the responsible radiographic inspector ensures that all nonmonitored personnel are clear of any area designated as a "radiation" or "controlled" area. This inspector also assures that all monitored personnel are positioned outside the perimeters of any potential high-radiation area.



Warning lights and an audible warning alarm signal are used when performing all radiographic exposures. A minimum of one warning light is located at each tubehead emission point, and one light is positioned at each control console. Whenever necessary, an additional warning light will be placed on any appropriate object or structure that is adjacent to the backup shielding or film area.

When using the Sperry 275-kilovolt peak (kvp) X-ray unit, additional warning lights are required. For this special-purpose unit, the minimum requirements for the use of warning lights and signs are depicted in Figure 1-7.

Radiation survey meters are used to monitor all areas subject to potential radiation during each in-tool type of radiographic exposure. Survey equipment is selected from those items approved by the Industrial Safety department. Selected instruments must be capable of measuring the types, energies, and levels of radiation expected to be encountered. A sufficient number of instruments is used to evaluate the entire controlled area for radiation levels. During a repetitious or a cyclic series of radiographic exposures, supplemental surveys are made any time the set conditions change from those established during the first exposure. Regardless of the number of surveys made to evaluate the radiation hazard, the total number of exposures is indicated on the Radiation Monitoring Record (Form 980-J-5). The energy levels and tube current utilized are also indicated on this form. Direct surveillance by certified personnel is exercised over the entire radiation area when X-ray operations are in progress.

Each radiation survey meter is tested before each use to assure operational capability. Faulty meters are not used. Survey meter readings are entered on Form 980-J-5 in accordance with existing safety procedures.

When using the field-emission pulse unit, a special dosimeter assigned to the machine is placed about 12 inches from the object to be X-rayed. The exact distance and the recorded reading after each exposure is entered on Form 980-J-5.

Note The presently assigned survey meters do not indicate the radiation intensity level when the pulse-type of unit is used (see Figure 1-8 for typical setup).

In the event of any radiation exposure to personnel that is suspected to exceed the acceptable level, the machine is immediately shut down and the procedures outlined in Industrial Safety Operations Standards are performed. Nondestructive Testing supervision is contacted as soon as possible for additional instructions.



Defective or inadequate equipment is not used; a withholding tag Form M59-B (Figure 1-19) is attached to the equipment and the discrepant condition reported to NDT supervision immediately upon discovery.

Nonstandard Field Type X-Ray Operations Performed Without Enclosed, Lead-Lined Rooms

All out-of-sequence X-ray inspection requests require prior approval of responsible NDT supervisors who evaluate each request to substantiate the need for such requirements. Written approval is acknowledged on the applicable radiation monitoring record.

When possible, all out-of-sequence exposures are made under the same conditions as planned sequence exposures. When it is not possible or feasible to attenuate radiation to the maximum 2-mr-per-hour intensity level at a distance of 3 feet, the following additional requirements then apply

1. The distance encompassing the 2-mr-per-hour radiation limit is computed by the responsible radiographic inspector, and a safety area perimeter greater than 3 feet is established. The distance for the newly established perimeter is entered on Form 980-J-5.
2. Barricades or other entry restrictions are placed at the newly established perimeter.
3. Warning signs are placed at strategic points around the perimeter. Warning lights are used at strategic locations (for example, the perimeter, doorways, etc.) if necessary in addition to the warning lights at the tube and the console.
4. Direct surveillance by certified personnel is exercised over the radiation area when X-ray operations are in progress.

Out-of-sequence exposures are performed in accordance with the most applicable of the sequences shown in Figures 1-8 or 1-12.

When repetitious exposures are required, a Job Improvement Request (JIR), Form M29-E, is initiated to procure tooling fixtures and associated shielding.

The field-emission pulse unit will not be used without a collimator except as specified herein

Again, if a radiation accident or incident occurs, Nondestructive Testing supervision is notified immediately, and the applicable portions of Industrial Safety Operations Standards are implemented.

Attenuation Assistance Tables

Occasionally, there is a requirement to perform unscheduled X-ray inspection tasks in areas with no normal tooling provisions. Normally, because these tasks are usually a one-time requirement, it would be uneconomical to provide special tooling for such inspection requirements. To provide for these nonstandard requirements, provisions have been included to accomplish the procedures in an efficient and safe manner. Tables 1-1, 1-2, and 1-3 are used as guides to facilitate computing radiation area perimeters and establish radiation shielding requirements. The measurements and values in the tables contain all the information necessary to compute the shielding and safe-distance requirements for any type of X-ray operation. The 21-inch focal film distance in Table 1-1 is the distance from the tubehead focal point to the end of the normal collimator length used, and the m/rem per hour listed are the average output of the X-ray machines.

Table 1-1. Guide for Determining Number of Milliroentgens Equivalent to Man (M/REM) Versus Kilovoltage and Focal Film Distance (FFD) Used

Focal Film Distance (inches)	Milliroentgens Equivalent to Man (M/REM)			
	50 kv	70 kv	100 kv	250 kv
21	8,800	17,630	70,530	352,650
12	27,000	54,000	216,000	1 080 000

Computation Steps

1. Establish the approximate number of M/REM—the figure located in the block horizontal with the FFD to be used and vertical in alignment with the kv to be used.
2. Multiply the figure established per Step 1 by the number of milliamperes (ma) to be used as determined from the applicable machine setting technique chart to compute radiation intensity (E).

Example $E = M/REM \text{ (from Table 1-1)} \times MA$

Table 1-2. Guide for Determining Number of Half-Value Layers (HVL) of Shielding Required to Reduce Radiation Intensity (E) to One Milliroentgen Equivalent to Man Per Hour (M/REM)

Number of HVL	Radiation Intensity (E)	Number of HVL	Radiation Intensity (E)
13	8,192	19	524,288
14	16,384	20	1,048,576
15	32,786	21	2,097,152
16	65,536	22	4,194,304
17	131,072	23	8,388,608
18	262,144	24	16,777,216

3. To establish the number of HVL required to reduce the radiation level to one M/REM per hour, select the next higher value of E from Table 1-2 that most approximately corresponds to E computed per Step 2.

Example If E (computed from Step 2) is 12,500, select HVL number of 14 (E = 16,384).

Table 1-3. Guide for Determining Thickness of Lead-Shielding To Be Used for Half-Value Layers (HVL) Versus Kilovoltage Used

HVL	50 kv	70 kv	100 kv	250 kv
1	0.002 inch	0.007 inch	0.010 inch	0.032 inch

- 4-a. To establish the thickness of lead-shielding to be used for a given operation, multiply the thickness shown in Table 1-3 for kv being used by the number of HVL computed per Step 3, Table 1-2

Example If the HVL is 14 and the kv is 70, the thickness of lead required is 0.098 inch (i.e., $0.007 \times 14 = 0.098$).

- 4-b. To establish the thickness of lead-impregnated vinyl to be used for the same operation, multiply the resultant figure calculated per Step 4-a by a factor of four.

Example: $0.098 \times 4 = 0.392$

Safety Guides

Figures 1-2 through 1-18 are used as basic guides to ensure that necessary safety precautions are observed during all radiographic operations not performed within a lead-lined room. Conditions encountered that are not similar to those in the referenced illustrations are referred to a nondestructive testing supervisor for clarification.

SAFETY REQUIREMENTS

1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING (B)** - 1/8-inch lead-impregnated vinyl (Leadex) is used to attenuate the primary radiation.
3. **COLLIMATORS (C)** - are used for all exposures and positioned as close to the part as is practicable.
4. **LEAD ATTENUATOR** - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. **COMMUNICATION (D)** - Positive communication is established between the machine operator and personnel inside a structure or with the tank entry controller if the structure is evacuated of personnel and entry is blocked.
6. **MULTIMACHINES (E)** - Can be simultaneously operated by one operator.
7. **BARRIERS** - During each exposure, the outside area is monitored and entry of unmonitored personnel is restricted in areas where radiation exceeds 2 mr per hour. The inside area is also monitored, if occupied.
8. **MONITORING** - Radiation levels are monitored and logged for each exposure.

NOTE: Leadex on the inboard side of the tank is not required if all personnel have been cleared of the area and entry to the inside of the tank is blocked.

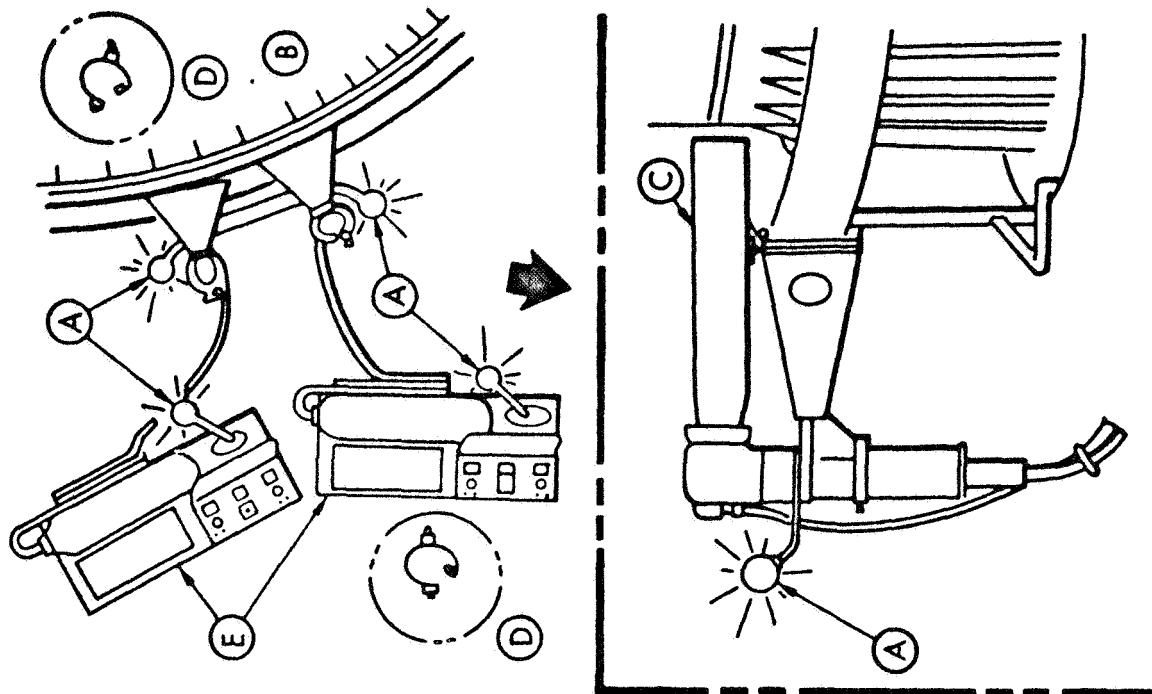
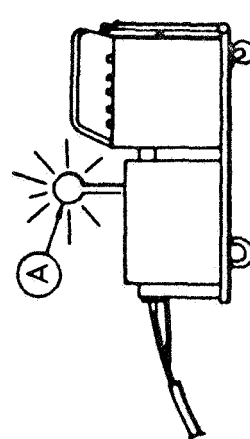


Figure 1-2. Circumferential Cylinder Welds (Stationary Tooling)

SAFETY REQUIREMENTS

1. WARNING LIGHTS (A) - A minimum of one light at the machine console and one light at each tubehead is required.
2. SHIELDING (B) - 1/8-inch Leadex is used to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. COLLIMATORS (C) - Are used for all exposures and positioned as close to the part as is practicable.
4. LEAD ATTENUATOR - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. COMMUNICATION - Direct visual and verbal contact is employed.
6. HOLDING FIXTURE (D) - A mechanically adjustable fixture, safely secured to a work stand, is utilized.
7. BARRIERS - Radiation warning signs to prevent entry into radiation areas are placed across the inside stairwell and the workstand ladder.
8. MONITORING - Radiation levels are measured and logged for each exposure.

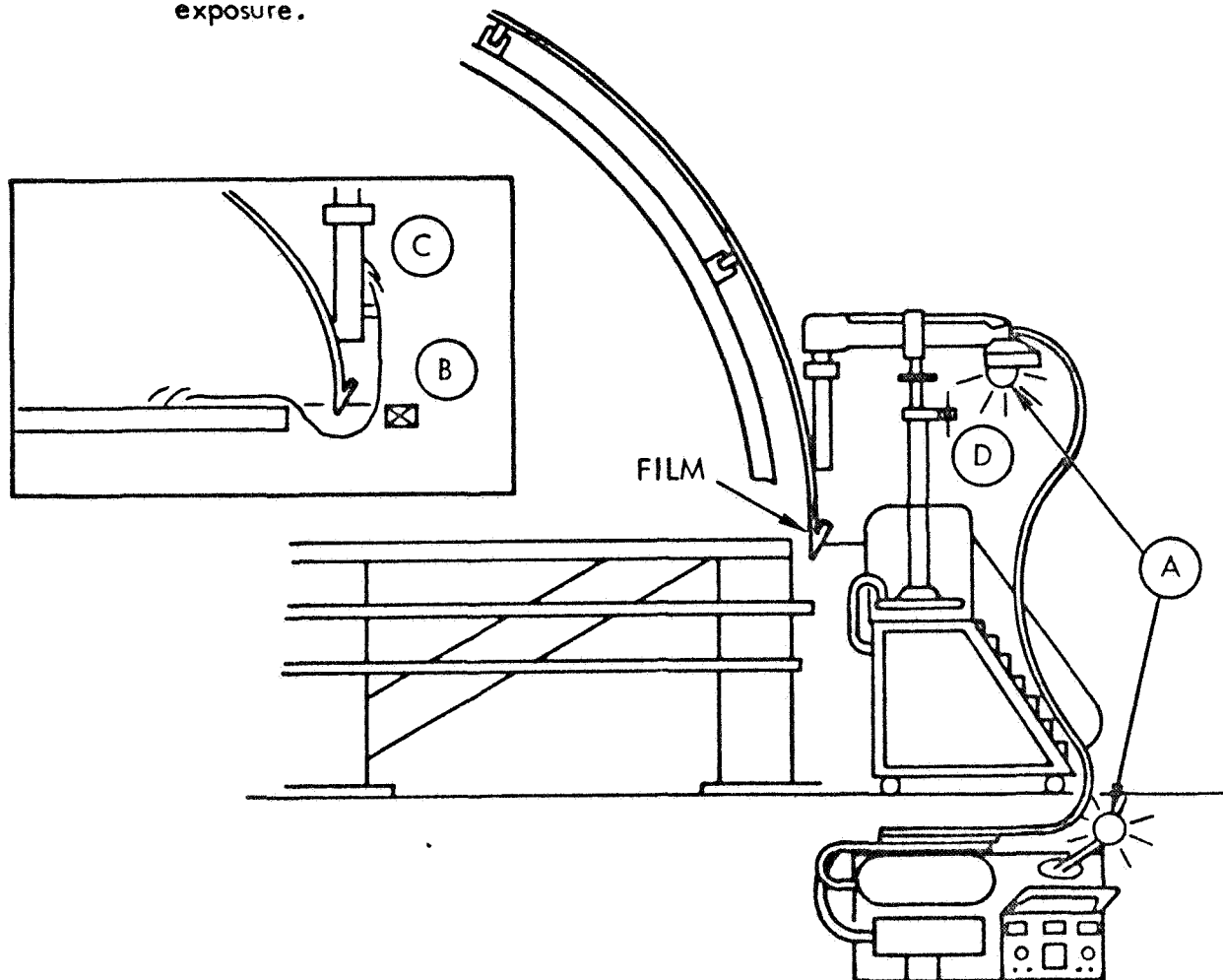


Figure 1-3. Forward Facing Sheet Welds, 'D' Views



SAFETY REQUIREMENTS

1. WARNING LIGHTS (A) - A minimum of one light at the machine console and one light at each tubehead is required.
2. SHIELDING (B) - 1/8-inch Leadex is used to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. COLLIMATORS (C) - Are used for all exposures and positioned as close to the part as is practicable.
4. LEAD ATTENUATOR - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. COMMUNICATION - Direct visual and verbal contact is employed.
6. HOLDING FIXTURE (D) - A mechanically adjustable stand, safely secured, is utilized.
7. BARRIERS - Radiation warning signs to prevent entry into the radiation area are placed across the tool entrance.
8. MONITORING - Radiation levels are monitored and logged for each exposure.

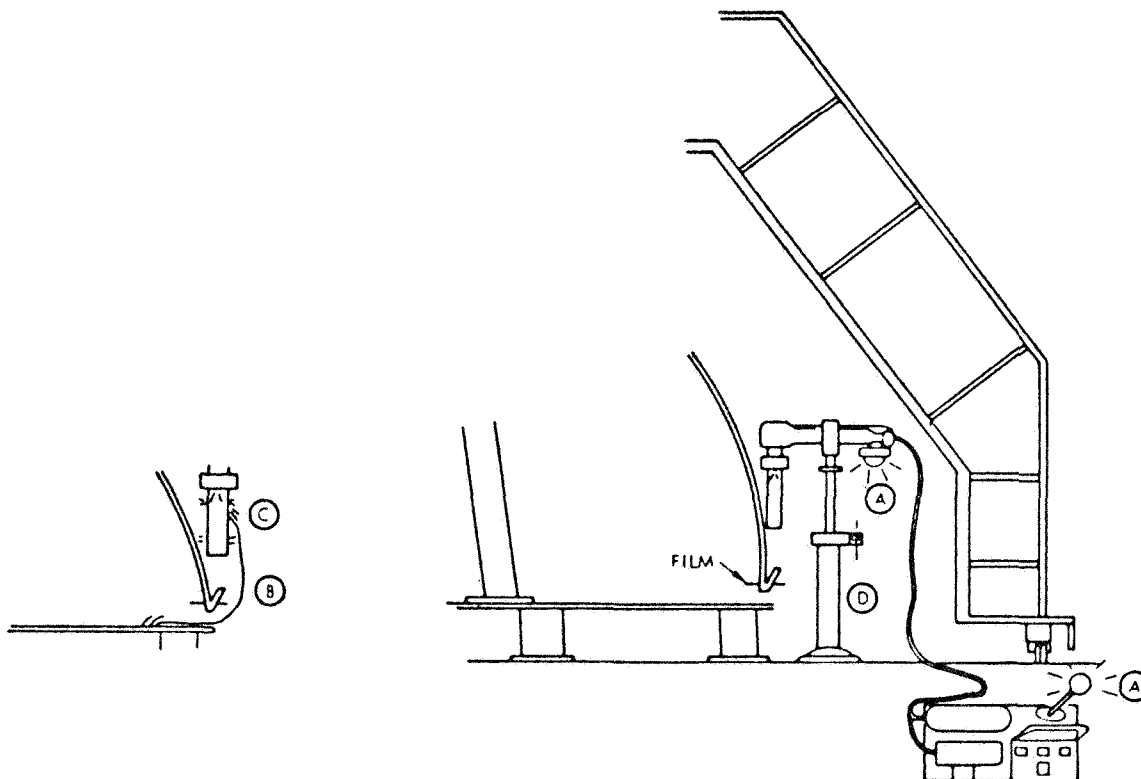


Figure 1-4. Forward Facing Sheet Welds, "D" Views

SAFETY REQUIREMENTS

1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING (B)** - 1/8-inch lead sheeting attached to the ladder is centered over the film and weld for attenuation of radiation.
3. **COLLIMATORS (C)** - Are used for all exposures and positioned as close to the part as is practicable.
4. **LEAD ATTENUATOR** - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. **COMMUNICATION** - Direct visual and verbal contact is employed.
6. **BARRIERS** - Radiation warning signs to prevent entry into the radiation area are placed across the stairwell inside the tool and the ladder on the outside of the tool.
7. **MONITORING** - Radiation levels are monitored and logged for each exposure.

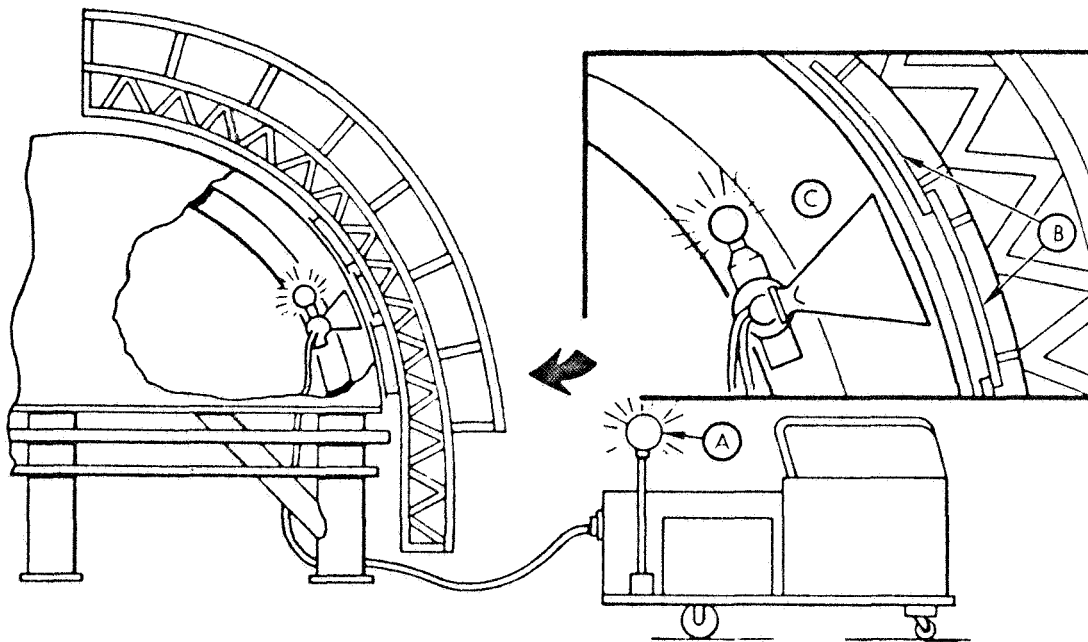
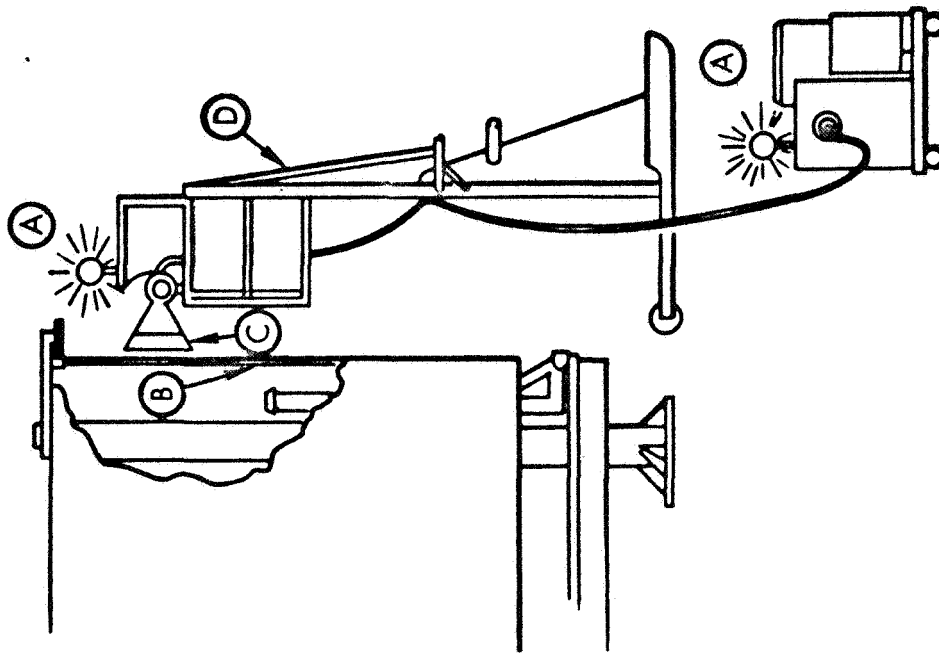


Figure 1-5. Bulkhead Meridian Welds (Stationary Tooling)



SAFETY REQUIREMENTS

1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING (B)** - 1/8-inch Leadex is used to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. **COLLIMATORS (C)** - Are used for all exposures and positioned as close to the part as is practicable.
4. **LEAD ATTENUATOR (D)** - Plugs and caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. **COMMUNICATION** - Direct visual and verbal contact is employed.
6. **BARRIERS** - Radiation warning signs to prevent entry into radiation area are placed at the stairwell tool entrance, on the "Hi-Boy" lift, and on the tool where it can be seen from the aisle. In addition, the entire area is physically controlled to prevent unauthorized entry.
7. **MONITORING** - Radiation levels are monitored and logged for each exposure.
8. **HOLDING FIXTURE (D)** - The tubehead and collimator are positioned and safely secured to the electrically adjustable Hi-Boy lift platform.

Figure 1-6. Cylinder Splice Welds (Stationary Tooling)

SAFETY REQUIREMENTS

1. **WARNING LIGHTS*** (A) Minimum of one light at the machine console is required. For this particular operation, one light is also located in the center of each hallway for the 4th, 5th, and 6th floors of the Vertical Assembly Building. (Personnel may be used in lieu of lights.)
2. **SHIELDING** (B) Special lead shields are positioned to attenuate the primary radiation to a minimal level. The shields overlap a minimum of 10 inches and extend 18 inches beyond the ends of the primary X-ray beam and are fastened together with pins.
3. **COLLIMATOR** A special collimator unit is used for all exposures. Appropriate adjustments are made to reduce the collimator opening to the minimum necessary for the required radiograph (0.350 x 3.0 inches).
4. **COMMUNICATION** (C) Positive verbal communication is established between the machine operator and the personnel controlling radiation area entry at each floor level. The Intercom is used continuously during exposure periods.
5. **BARRIERS*** (D) **EXTERIOR DOORS:** All exterior access doors to the radiation area are mechanically locked and radiation signs are posted on doors.
GUARDS: Guards with survey meters are posted to prevent entry by unauthorized personnel into the radiation area at the following locations:
 1. Stairwell - at entry to 4th floor level.
 2. Hallway - midpoint at 4th, 5th, and 6th floors.
6. **RADIATION AREA*** 1. Station and adjacent station of the X-ray source for 4th, 5th, and 6th floors.
 2. Hallways from point of X-ray source to center of building on 4th, 5th, and 6th floors.
7. **RADIATION LEVELS** All noncontrolled occupied areas are monitored to assure the radiation level does not exceed 15 MR per hour intensity during exposure cycles. Radiation levels obtained are recorded for each exposure.
8. **MACHINE** (E) Operator and X-ray console are located aft of a lead manshield located in the hallway outside of the applicable station.
9. **ELEVATORS** (F) Freight - is deactivated.
 Passenger - can remain operational when location of X-ray machine is in Station IV
 Passenger - deactivated when location of X-ray machine is in Station II.

* If radiographic operations are performed on the 6th floor, the 4th floor restrictions do not apply (only 5th and 6th floors affected).

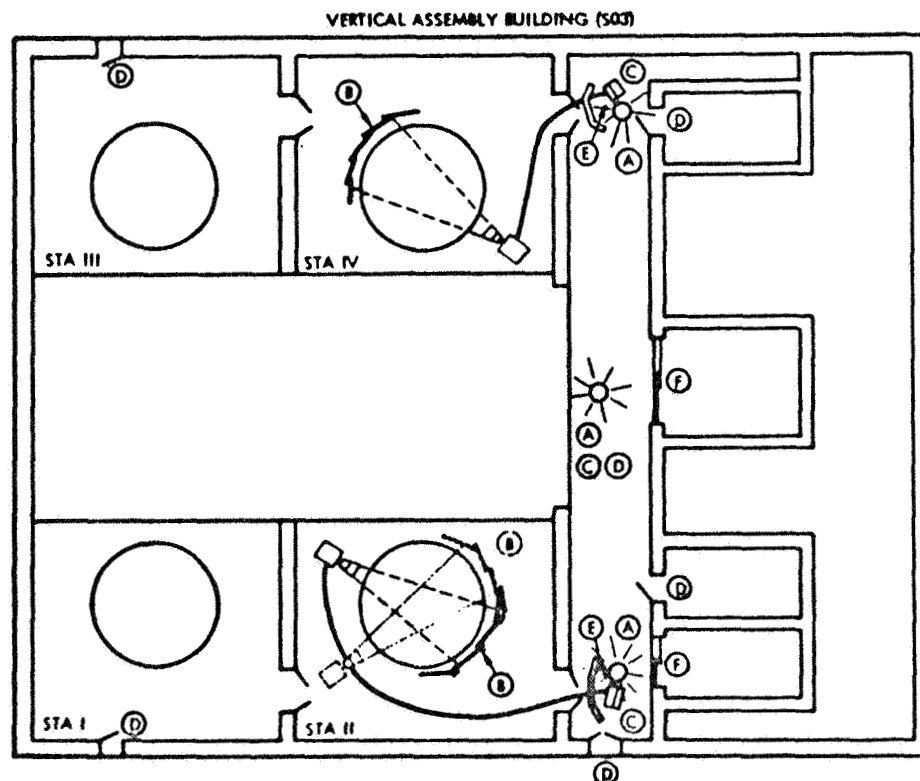


Figure 1-7. Debris Search Radiographs (Sperry 275-kv Unit)

SAFETY REQUIREMENTS

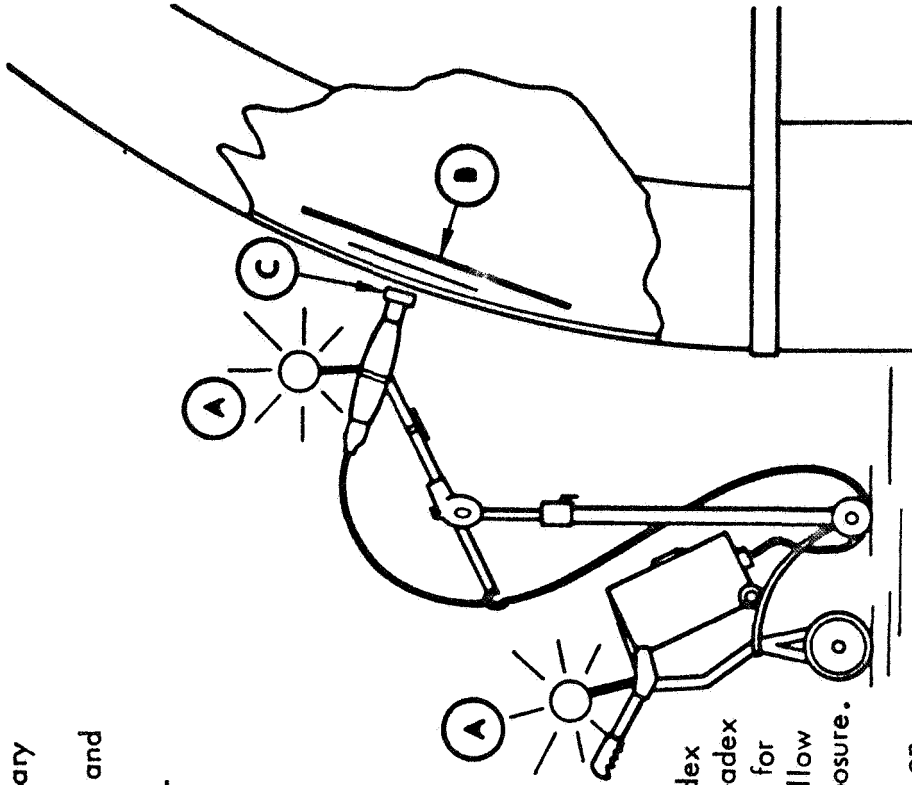
1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING (B)** - 1/8-inch Leadex is used to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. **COLLIMATOR (C)** - Special collimator is used for all exposures and is positioned as close to the part as is practicable.
4. **DOSIMETER** - Is placed approximately 12 inches from the tubehead emission point. The exact distance and the readings for each exposure are entered on Form 980-J-5.
5. **RADIATION** - The radiation area with collimator installed is established as:

Focal Film Distance	Radius of Radiation Area
3 inches	1 foot
6 inches	2 feet
12 inches	3 feet
18 inches	4 feet
over 18 inches	4 feet

NOTE: The radiation area can be reduced by use of lead or Leadex shielding. Lead measuring 1/32 inch in thickness or 1/8-inch Leadex will reduce the 90-degree scatter radiation to a level that is safe for normal functions. Hence, use of vinyl Leadex shielding would allow occupancy of any area so shielded to within six inches of the exposure. Areas with employees working close to the tubehead will have a dosimeter placed adjacent to personnel and the readings recorded on Form 980-J-5.

6. **MACHINES** - Are not under any circumstances operated over 100 pulses without allowing a 4-minute cooling period before performing a subsequent operation.
7. **MONITORING** - Radiation levels are monitored and logged for each exposure.

Figure 1-8. Common Bulkhead Information Radiographs (Pulse Unit)



SAFETY REQUIREMENTS

1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING (B)** - 1/8-inch Leadex is used to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. **COLLIMATORS (C)** - Are used for all exposures and positioned as close to the part as is practicable.
4. **TUBEHEAD** - After setup, lead tube-plug or collimator endcover is installed when machine is not in use or when radiographer is not in attendance.
5. **COMMUNICATION (D)** - Positive verbal communications are established between the machine operator and personnel inside the structure.
6. **MULTIMACHINES** - Can be simultaneously operated by one operator.
7. **BARRIERS** - Are placed closely around transporter perimeter to comply with radiation level requirements defined in Item 2.
NOTE: Stud finder and magnet are used at random locations to assure correct collimator alignment.
8. **HOLDING FIXTURE** - Tubeheads and collimators are positioned and safely secured to portable tube-holding stands.
9. **MONITORING** - Radiation levels inboard and outboard are monitored and logged for each exposure.

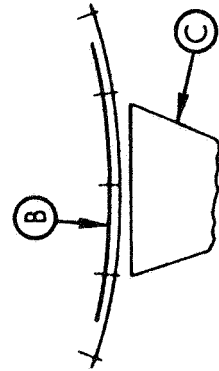
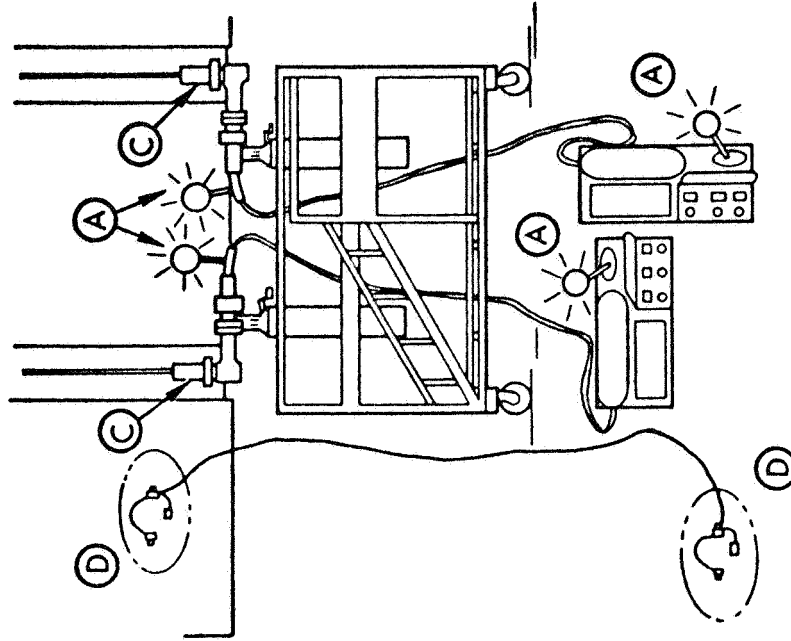


Figure 1-9. Circumferential and Cylinder Welds (Post-Pneumatic Test Evaluation)



SAFETY REQUIREMENTS

1. WARNING LIGHTS (A) - A minimum of one light at the machine console and one light at each tubehead is required.
2. SHIELDING (B) - 1/8-inch/lead-impregnated vinyl is used to attenuate the primary radiation level to 2 mr per hour or less at a distance of 3 feet.
3. COLLIMATORS (C) - Are used for all exposures and positioned as close to the part as is practicable.
4. LEAD ATTENUATOR - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. COMMUNICATION (D) - Positive verbal communication is established between the machine operator and the radiographer inside the bulkhead.
6. BARRIERS - If backup shielding is not used, radiation warning signs are placed at three doors leading into Station V and across the stairwell leading to the platform beneath the bulkhead entrance. Two guards are posted within the station to prevent entry of unauthorized personnel into the radiation area.
7. MONITORING - Radiation levels are monitored and logged for each exposure.
8. HOLDING FIXTURE (E) - A mechanically adjustable tripod, safely secured, is utilized.

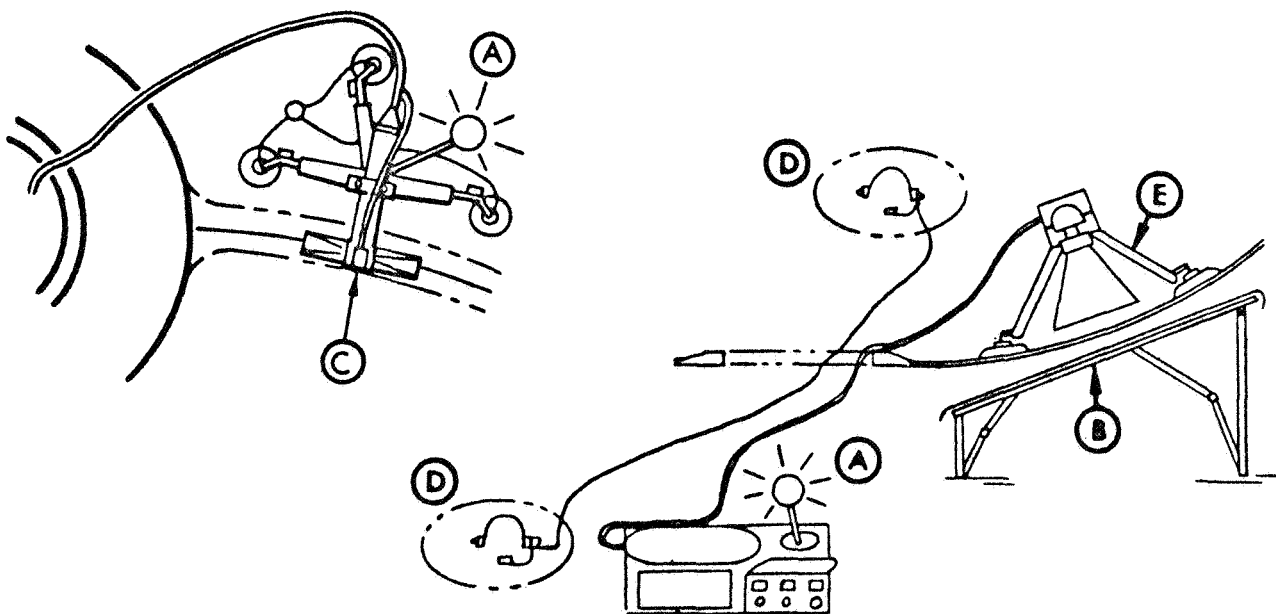


Figure 1-10. Forward LH₂ Bulkhead Meridian and Dollar Welds
(Post-Pneumatic Test Evaluation, Station V)

SAFETY REQUIREMENTS

1. WARNING LIGHTS (A) - A minimum of one light at the machine console and one light at each tubehead is required.
2. SHIELDING (B) - 1/8-inch Leadex is used to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. COLLIMATORS (C) - Are used for all exposures and positioned as close to the part as is practicable.
4. LEAD ATTENUATOR - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. COMMUNICATION - Direct visual and/or verbal contact is employed.
6. HOLDING FIXTURE - A mechanically adjustable stand, safely secured, is utilized.
7. BARRIERS (D) - Barriers are established using Magenta rope to assure compliance with radiation level requirements defined in Item 2. Radiation warning signs are used to restrict entry of unmonitored personnel into radiation areas.
8. MONITORING - Radiation levels are monitored and logged for each exposure.

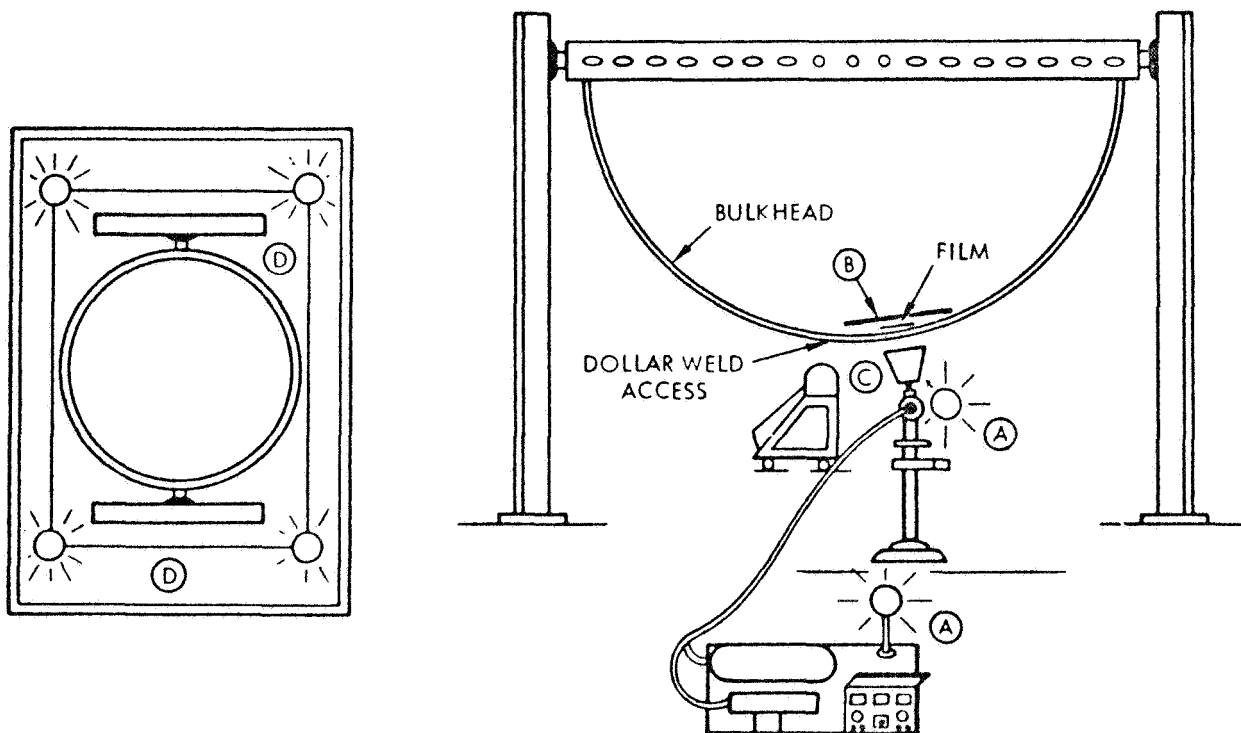


Figure 1-11. Bulkhead Dollar Welds (Turnover Fixture)

SAFETY REQUIREMENTS

1. WARNING LIGHTS (A) - A minimum of one light at the machine console and one light at each tubehead is required.
2. SHIELDING (B) - 1/8-inch Lead α x is used to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. COLLIMATORS (C) - Are used for all exposures and positioned as close to the part as is practicable.
4. LEAD ATTENUATOR - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. COMMUNICATION - Direct visual and verbal contact is employed.
6. HOLDING FIXTURE (D) - A mechanically adjustable stand, safely attached or secured to a workstand, is utilized.
7. BARRIERS (E) - A barrier is established using Magenta rope to assure compliance with radiation level requirements defined in Item 2. Radiation warning signs and red warning lights are placed in appropriate locations. Direct physical surveillance is also maintained during each exposure cycle to prevent entry of unauthorized personnel into radiation area.
8. MONITORING - Radiation levels are monitored and logged for each exposure.

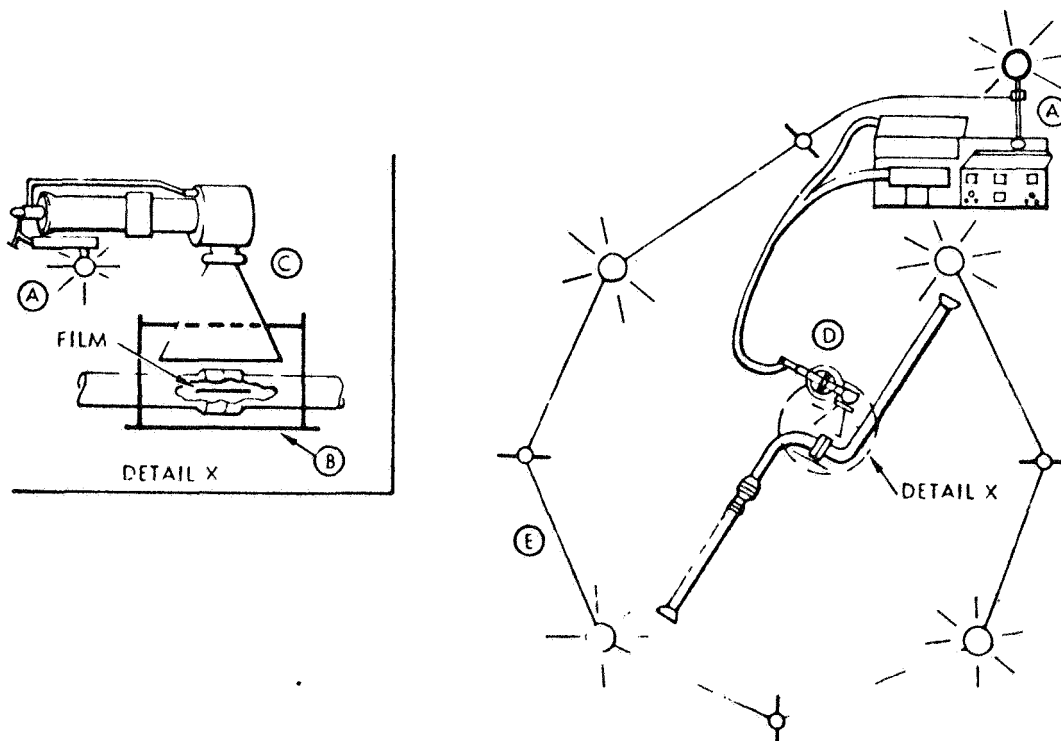


Figure 1-12. Miscellaneous Out-of-Sequence Radiographs (Electrical Connectors, Installed Lines, Valves, Etc.)

SAFETY REQUIREMENTS

1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING (B)** - 1/8-inch Leadex is used to attenuate the primary radiation level to 2 MR or less at a distance of 3 feet.
3. **COLLIMATORS (C)** - Are used for all exposures and positioned as close to the part as is practicable.
4. **LEAD ATTENUATOR** - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. **COMMUNICATION** - Direct visual and verbal contact is employed.
6. **BARRIERS** - Radiation warning signs are placed across the ladder inside the tool and at the tool entrance to prevent entry of unauthorized personnel into radiation areas.
7. **MONITORING** - Radiation levels are monitored and logged for each exposure.

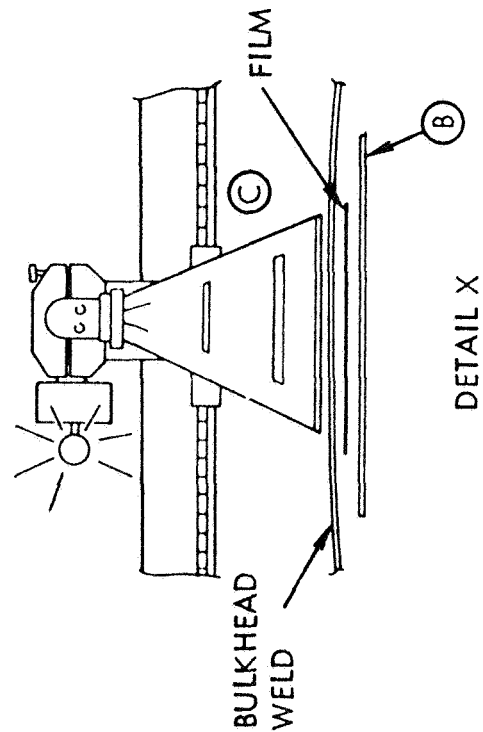
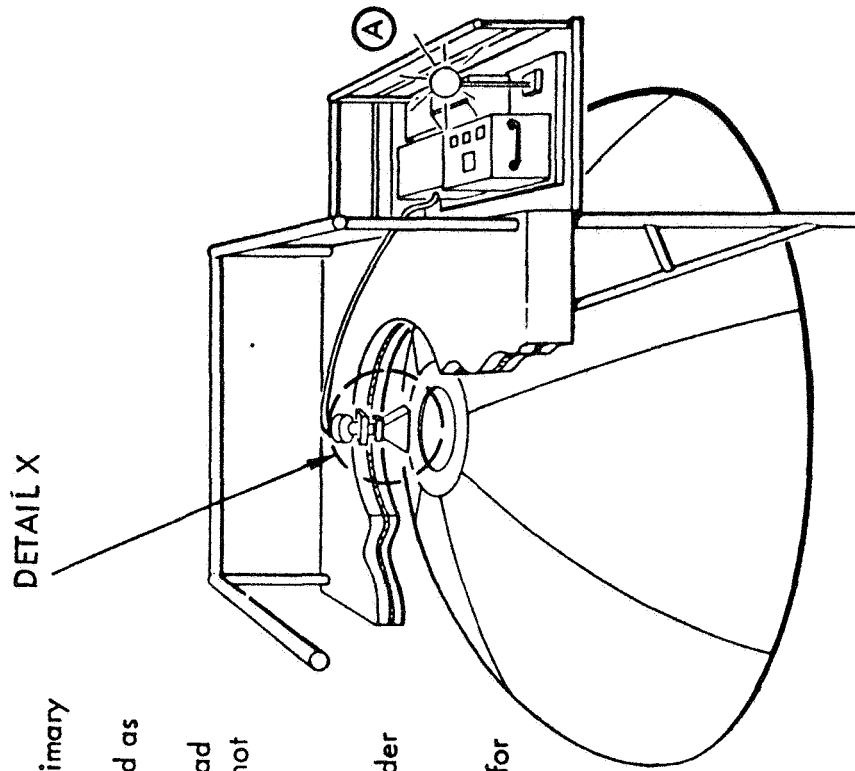


Figure 1-13. Bulkhead Dollar Welds

SAFETY REQUIREMENTS

1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING (B)** - 1/8-inch Leadex will be centered over the weld and film to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. **COLLIMATORS (C)** - Are used for all exposures and positioned as close to the part as is practicable.
4. **LEAD ATTENUATOR** - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. **COMMUNICATION (D)** - Positive verbal communication is established between the machine operator and the personnel inside the structure.
6. **BARRIERS** - Radiation warning signs are placed at the tool entrance. The second operator inside the tool monitors each exposure and prevents entry of all unauthorized personnel into radiation area.
7. **MONITORING** - Radiation levels are monitored and logged for each exposure.

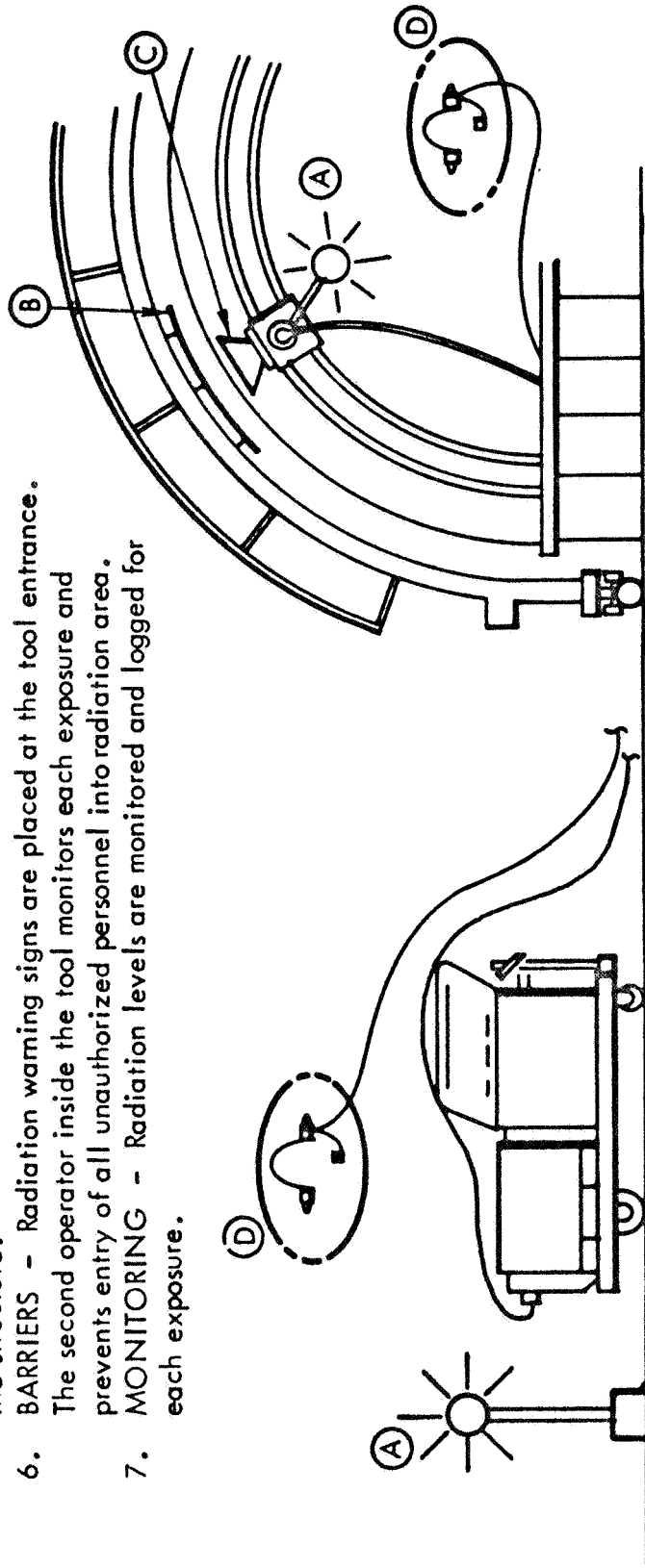
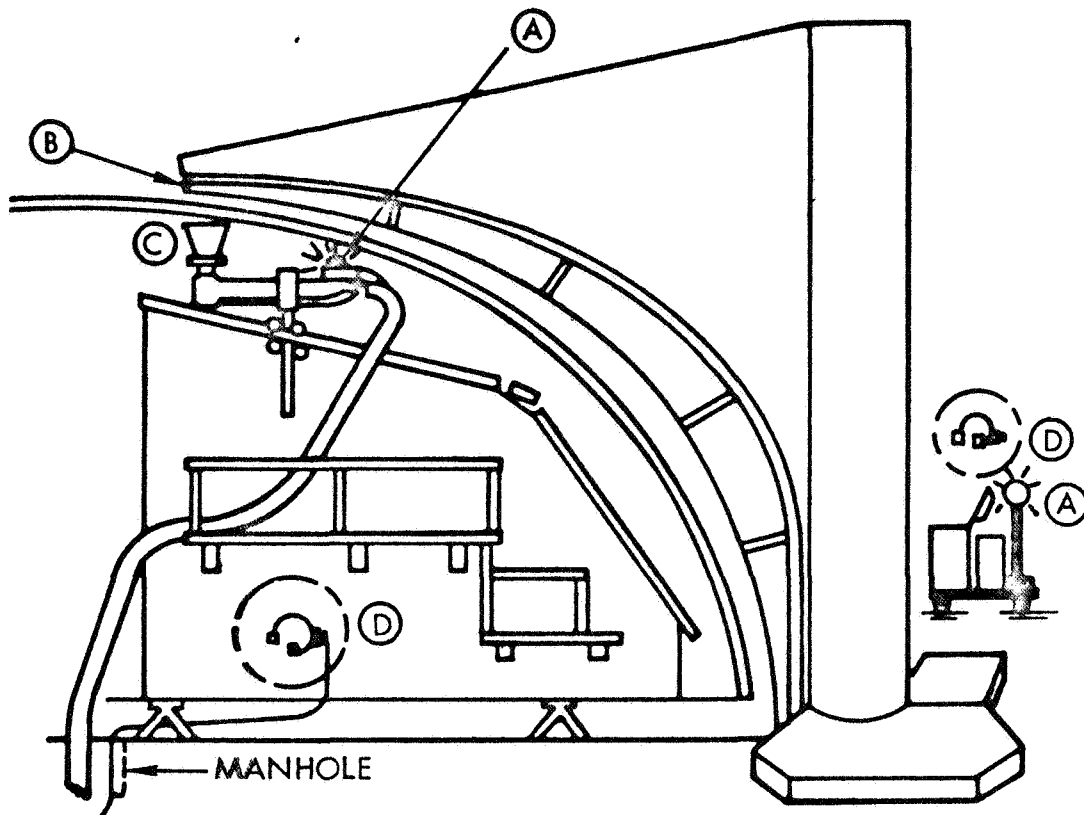


Figure 1-14. Bulkhead Welds (Post-Hydrostatic Test Evaluation, Tracing Tool)



SAFETY REQUIREMENTS

1. WARNING LIGHTS (A) - A minimum of one light at the machine console and one light at each tubehead is required.
2. SHIELDING (B) - 1/8-inch lead sheeting attached to the ladder is centered over the weld and film to attenuate the primary radiation.
3. COLLIMATORS (C) - Are used for all exposures and positioned as close to the part as is practicable.
4. LEAD ATTENUATOR - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. COMMUNICATION (D) - Positive verbal communication is established between the machine operator rotating the tool between exposures and the radiographic operator inside the structure.
6. BARRIERS - Radiation warning signs are placed across the man-hole entrance to the ultrasonic tool. The machine operator is also positioned to ensure surveillance of both the man-hole entrance and the exterior area of exposure (ladder) to prevent entry of unauthorized personnel into the radiation zone.
7. MONITORING - Radiation levels are monitored and logged for each exposure.

Figure 1-15. Bulkhead Welds (Post-Hydrostatic Test Evaluation, Ultrasonic Tool)

SAFETY REQUIREMENTS

1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING (B)** - 1/8-inch Leadex is used to attenuate the primary radiation to 2 MR per hour or less at a distance of 3 feet.
3. **COLLIMATORS (C)** - Are used for all exposures and positioned as close to the part as is practicable.
4. **LEAD ATTENUATOR** - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. **COMMUNICATION (D)** - Positive verbal communication is established between the console operator and the X-ray technician inside the structure.
6. **BARRIERS** - A barrier is established using Magenta rope to assure compliance with radiation level requirements defined in Item 2. Radiation warning signs are placed in appropriate locations. The machine operator also maintains surveillance of the zone to prevent entry of unauthorized personnel into the radiation area.
7. **MONITORING** - Radiation levels are monitored and logged for each exposure.

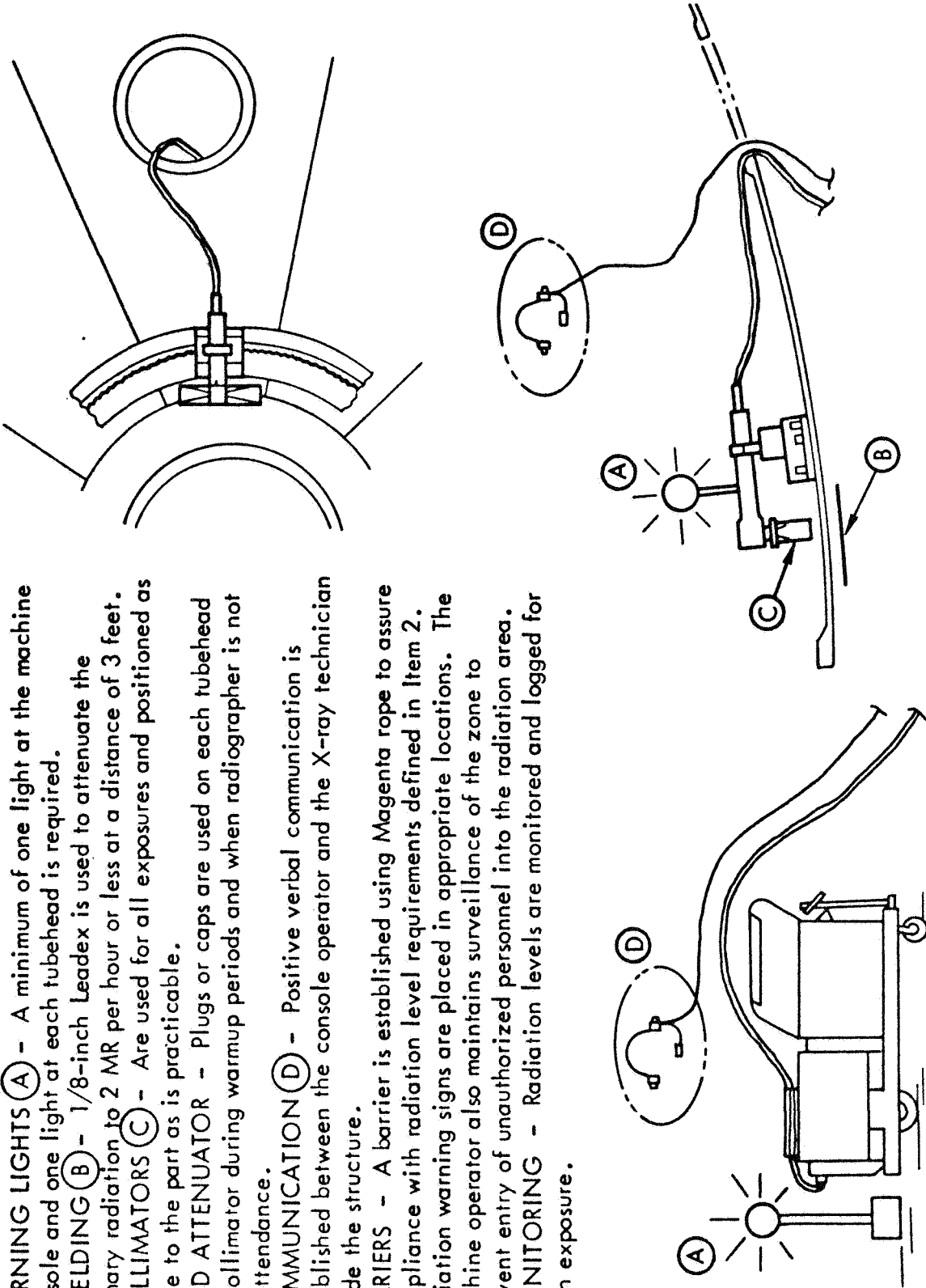


Figure 1-16. Aft LO2 Bulkhead Dollar Welds (60-Foot Extension)

SAFETY REQUIREMENTS

1. **WARNING LIGHTS (A)** - A minimum of one light at the machine console and one light at each tubehead is required.
2. **SHIELDING** - An autoclave cover is used over the structure whenever possible.
3. **COLLIMATORS (B)** - Are used for all exposures.
4. **LEAD ATTENUATOR** - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. **COMMUNICATION** - Direct visual and verbal contact is employed.
6. **HOLDING FIXTURE (C)** - A mechanically adjustable stand or howitzer, safely secured, is utilized.
7. **BARRIERS (D)** - When the autoclave cover is not positioned over the structure, a six-foot safety area around the circumference of the tool is established using Magenta rope, radiation warning signs, and/or lights. The machine operator and the radiographer, working as setup men, act as guards, positioning themselves on the outside to allow 100 percent surveillance of the area to prevent entry of unauthorized personnel into the radiation zone. When the cover is in place, only the zone inside the bulkhead is considered a radiation area and is monitored to prevent entry.
8. **MONITORING** - Radiation levels are monitored and logged for each exposure.

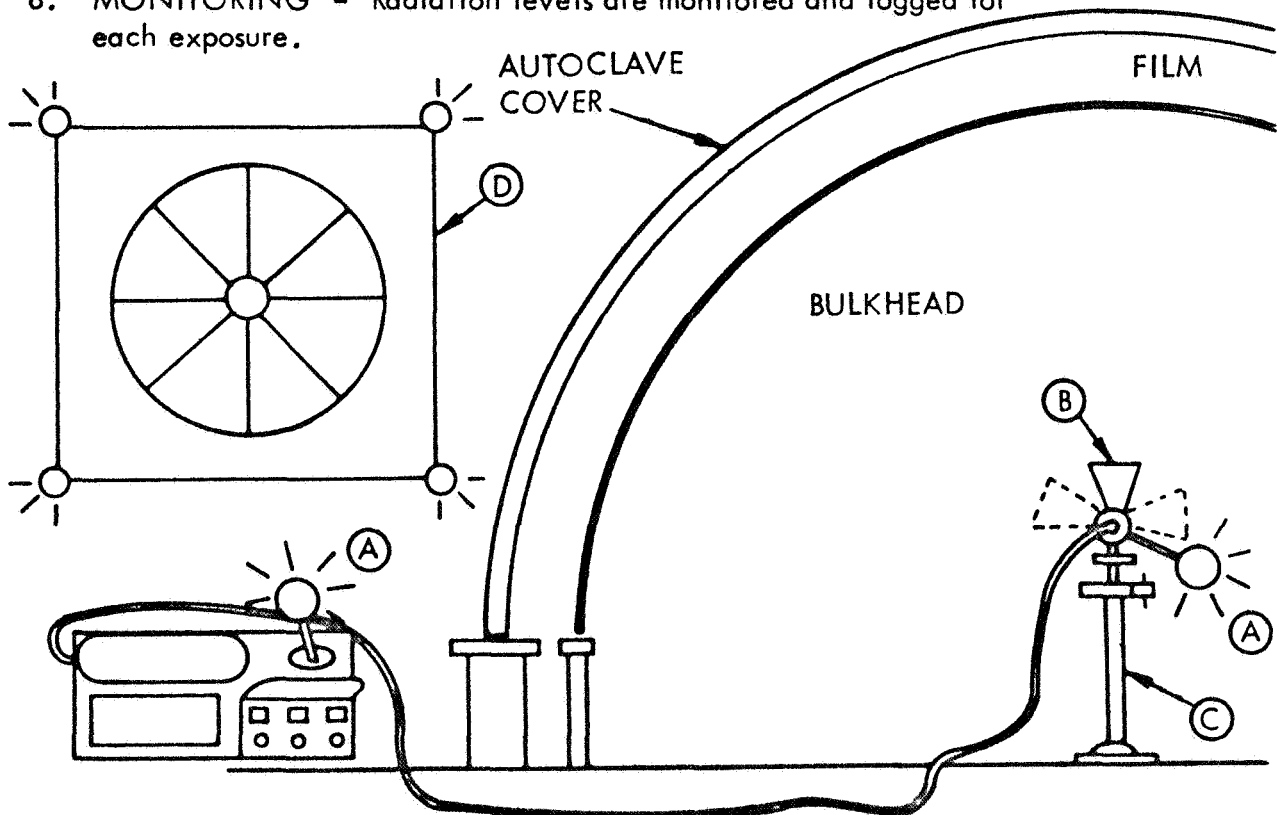


Figure 1-17. Common Bulkhead Void Indication Evaluations (Rework Tool)

SAFETY REQUIREMENTS

1. WARNING LIGHTS (A) - A minimum of one light at the machine console and one light at each tubehead is required.
2. SHIELDING (B) - 1/8-inch Leadex is used to attenuate the primary radiation level to 2 MR per hour or less at a distance of 3 feet.
3. COLLIMATORS (C) - Are used for all exposures and positioned as close to the part as is practicable.
4. LEAD ATTENUATOR - Plugs or caps are used on each tubehead or collimator during warmup periods and when radiographer is not in attendance.
5. COMMUNICATION (D) - Positive verbal communication between the machine operator, the man rotating the stage, and the radiographer inside the structure is employed.
6. HOLDING FIXTURE (E) - A portable X-ray tube holding stand, safely secured, is utilized.
7. BARRIERS - Appropriate radiation warning signs are placed around the stage transporter to assure compliance with radiation level requirements defined in Item 2 and to prevent entry of unauthorized personnel into the radiation area. NOTE: A stud finder and Magnet check is used at random locations to assure that correct collimator alignment is achieved.
8. MONITORING - Radiation levels are monitored and logged for each exposure.

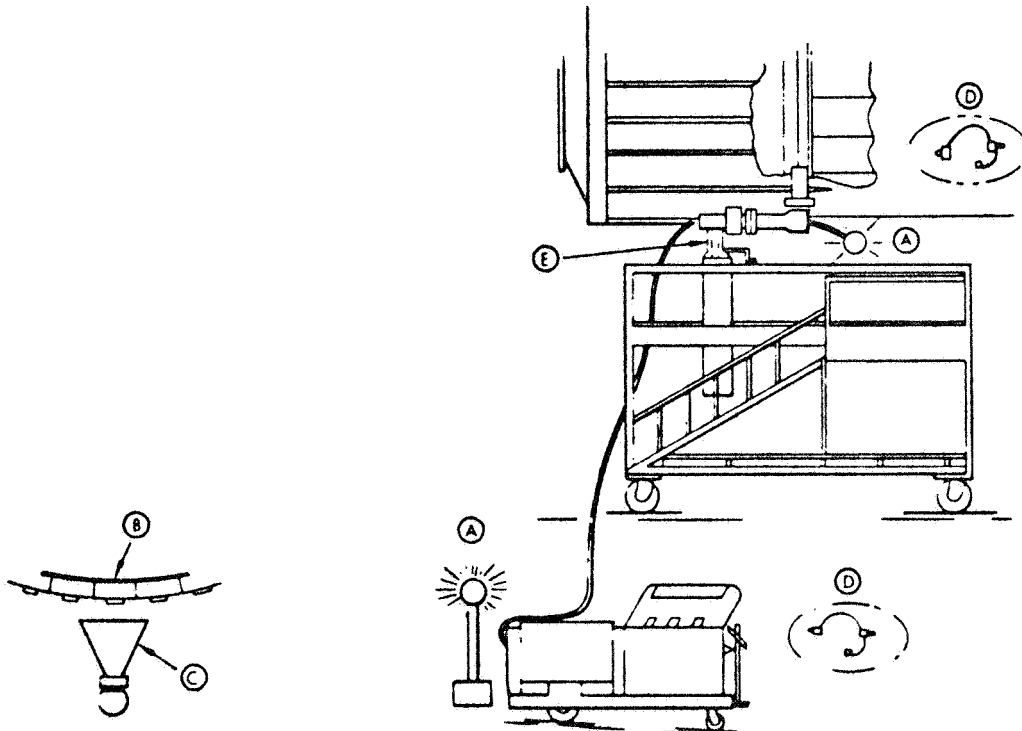


Figure 1-18. Cylinder 6 Forward LH2 Bulkhead Welds After Installation of Forward Skirt Assembly



WITHHOLD				
UNAUTHORIZED REMOVAL OF THIS TAG PROHIBITED				
QTY	N	L	189763	
QTY.	N	N		
PART NAME				
PART NUMBER			SERIAL NUMBER	
REASON FOR WITHHELD				
CONTROL NUMBER				
INSPECTION	DATE	INSPECTION	DATE	REMARKS
FORM M59-B REV. 12/68				

Figure 1-19. Form M59-B



1.2 WARMUP AND CHECKOUT INSTRUCTIONS AND PROCEDURES FOR X-RAY MACHINES

This section describes the sequence used during X-ray machine warmup and/or checkout operations.

All personnel operating X-ray machines should be cognizant of the procedures contained in this section. These procedures are followed to assure personnel safety and preclude inadvertent damage to X-ray equipment (tubes).

Any X-ray machine that has not been in use during the previous four hours is warmed up prior to use in accordance with the instructions defined herein. As soon as practicable, any X-ray machine received after maintenance is warmed up and checked out in accordance with the following

1. A lead plug is installed in the tubehead collimator attachment to attenuate radiation leakage to 0.5 or less mr at a distance of 3 feet. Attenuation can also be accomplished with the collimator installed by placing a lead cover plate over the end of the collimator.
2. The applicable precautions of Section 1.1 must be observed prior to energizing the machine.
3. At the time of the machine warmup, the area completely around the tubehead (360 degrees) is surveyed with a radiation survey meter for any radiation leakage. Any unusually high radiation readings are cause for immediate shutdown of the X-ray machine. The operator attaches a withholding tag to the machine and notifies the NDT Supervisor of the defective equipment.
4. The sequential warmup procedure is accomplished as follows
 - a. Start machine at 50-percent voltage and current
 - 150-kv units - 75 kv
6 ma
 - 100-kv units - 50 kv
4 ma
 - 275-kv unit - 150 kv
5 ma

- b. Increase kv and ma outputs in increments of approximately 10 percent while operating the machine for approximately 4 minutes per increment until the output required for the task is reached.
- c. Prior to shutting the units down, allow the cooling system to operate an additional 10 minutes after completion of any exposure or series of exposures.

NOTE If the X-ray machine has been in operation during the preceding four hours, no warmup is necessary.



1 3 RADIOGRAPHIC INSPECTION OF WELDS AFTER FABRICATION AND PRESSURE TESTING

This section presents detailed sequences followed by Quality Assurance personnel in performing radiographic inspections of Saturn S-II I H_2 and LO_2 tank welds with conventional X-ray producing machines

Personnel who perform Saturn S-II radiographic inspection operations must be cognizant of the information contained herein. This section describes each sequence associated with radiographic inspection of the various welds contained in the Saturn S-II propellant tanks. These instructions should be used in conjunction with the requirements specified in NR SD Quality Control Specification MQ0501-007, 'Inspection, Radiographic, and NDT Desk Instruction No. 10, Standard Radiation Safety Procedures for the Seal Beach Facility Using Conventional X-ray Producing Machines'. The radiographic inspection requirements after pressure testing are as specified in NR SD Inspection and Test Instructions, ITI-3525, Special Inspection Verification - Propellant Tanks "

Certain basic equipment is essential to perform any radiographic operation. The following equipment is common to all tasks described in Section 1.3. However, the additional accessory equipment items presented under each task description are considered essential to that particular operation.

- 1 Film badge and dosimeter
- 2 Radiation log sheet (Form 980-J-5)
3. Radiation survey meter (calibrated)
4. X-ray tubehead collimator
5. X-ray machine (including associated controls, power generator, cooling unit, and warning lights)
- 6 X-ray tubehead holding fixture
7. X-ray machine exposure curve
8. Material thickness chart
- 9 Penetrameters

10. X-ray control number

11. Industrial X-ray film

Identification belts have been prepared for most of the tank and bulk-head welds. These belts are made of a flexible Mylar material impregnated with an X-ray opaque material in increments to orient the radiographs to the specific location on the assembly. The impregnated material provides a density contrast on the film that will fully identify the needed orientation but will not cause eye discomfort during the radiographic interpretation. The number belts prepared for the circumferential welds and vertical weld splices are divided into inch increments and contain trimline identification markers. All belts contain reference markers that index the belts to reference marks etched on the assemblies.

Figure 1-20 shows a prepared number belt for a circumferential weld, a survey meter, a pocket dosimeter, a film badge, three penetrameters, and a strip of industrial X-ray film.

1.3.1 BULKHEAD MERIDIAN WELDS AFTER FABRICATION

Special Equipment and Materials Required

A. Lead identification markings

1. Continuous individual numbers 0 through 24 (continuous individual numbers 0 through 21 for the aft LO₂ bulkhead only)
2. Letters ENTTL (equatorial net trimline) and DNTTL (dollar net trimline) (Letters A, B₁, B₂, C, and D for the common bulkhead forward facing sheet only)

NOTE Prepared number belts may be used in lieu of the above.

3. X-ray control number

B. Industrial X-ray film (Kodak, type "M") 70 mm

1. Two film strips, each 21 feet in length, for the forward facing sheet, the aft facing sheet, and the forward LH₂ bulkhead
2. Two film strips, each 18 feet in length, for the aft LO₂ bulkhead.

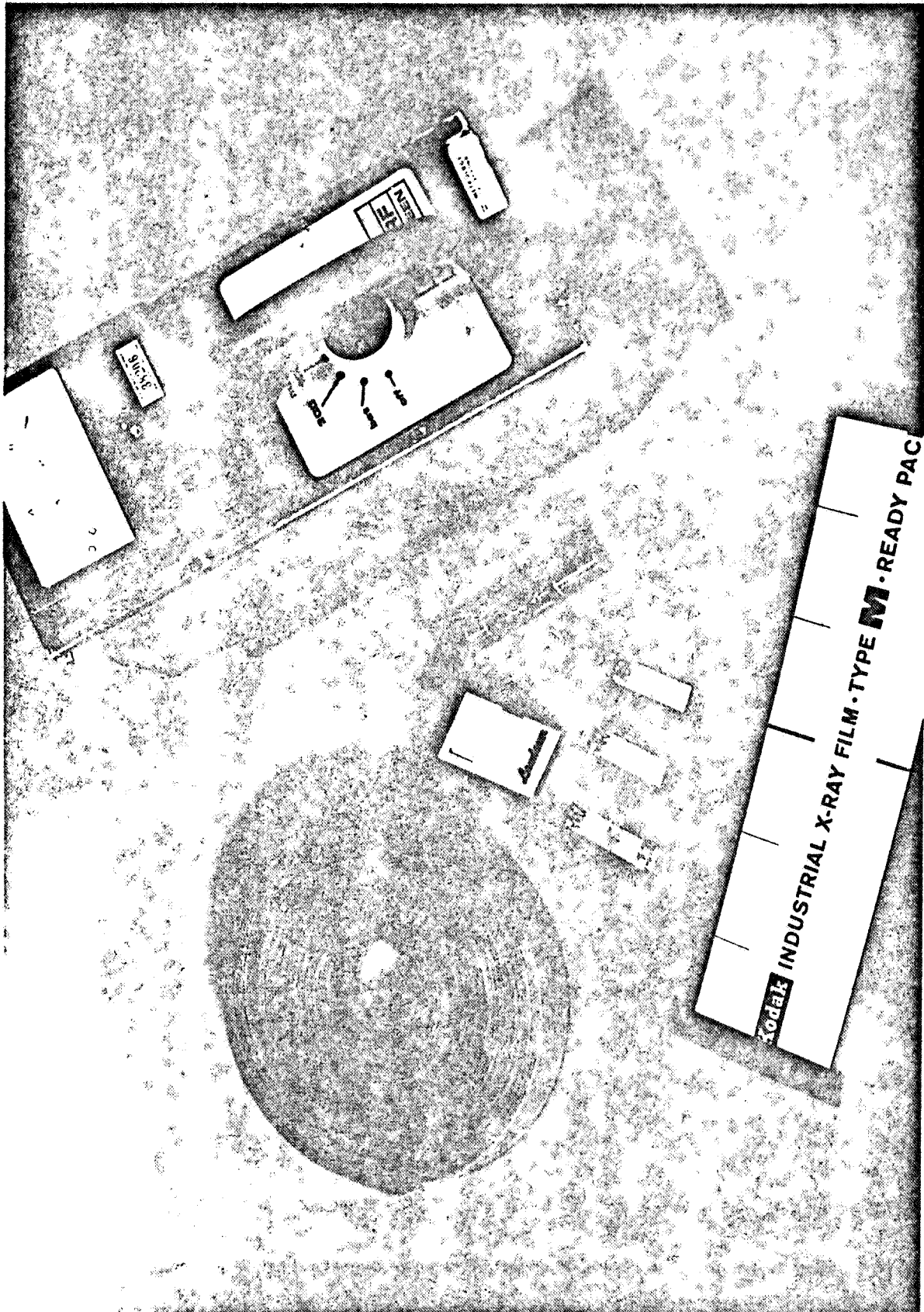


Figure 1-20. X-Ray Equipment

700-60-89



3. Four additional film strips, each 12 inches in length, for the forward facing sheet "J" section
4. One strip cut to 1-1/2 inches in width and 6 inches in length also for the "J" section

Procedure for Inspection

A. Placement of identification markings

1. Place X-ray view number identification markers on the inside surface of the bulkhead. Numbers are to be located on the left-hand side, facing weld from the inboard side. If an X-ray view number belt is used, it is also placed on the left-hand side inboard surface 1/4 inch from the edge of the weld.
2. Place view number "0" at the ENTL adjacent to the weld on all bulkheads except the forward facing sheet where view "0" will be placed 3.310 inches above the ENTL. The 3.310-inch dimension is located at the radius of the 0.220-inch-thick material to the 0.125-inch material. (See Figure 1-24.)
3. Place an arrow marker with the identification ENTL on the right-hand side, adjacent to the weld identifying the equatorial net trimline.
4. Position view numbers numerically on the left-hand side of the weld, starting from the equatorial net trimline to the dollar net trimline in 10-inch increments.
5. Place an arrow marker with the identification DNLT on the right-hand side, adjacent to the weld identifying the dollar net trimline.

B. Placement of X-ray film

1. Place one 21-foot strip of X-ray film on the exterior (outboard) surface of the weld taking care to assure that the film is centered over the weld and overlaps the edges of the panels at both ends.
2. Rotate the contour ladder on which the lead backup shielding is secured to a position directly over the weld. (See Figure 1-21.)

C. Setup of X-ray equipment (Figure 1-21.)

1. Position the X-ray machine (100-kv tubehead) as near as possible to the underneath side of the bulkhead assembly tool.
2. Insert the X-ray tubehead through the square hole in the floor of the bulkhead assembly tool. Provide a sufficient length of tubehead cable to reach the apex of the bulkhead.
3. Secure the X-ray tubehead into the skate fixture (Figure 1-22).
4. Remove the lead protective cover (plug) and install the collimator (Figure 1-23).

CAUTION

Do not leave X-ray console unattended without replacing lead plug on tubehead or placing lead cover on collimator opening (Figure 1-23)

5. Align the collimator with the weld centerline and position at View 0-1.

D. Exposure procedure

1. Determine the material thickness from the thickness chart.
2. Select the proper machine settings from the technique curve.
3. The X-ray machine is activated after adherence to all safety procedures.
4. Expose all even-numbered views (i.e., 0-1, 2-3, 4-5, etc.) for the entire length of the meridian weld.

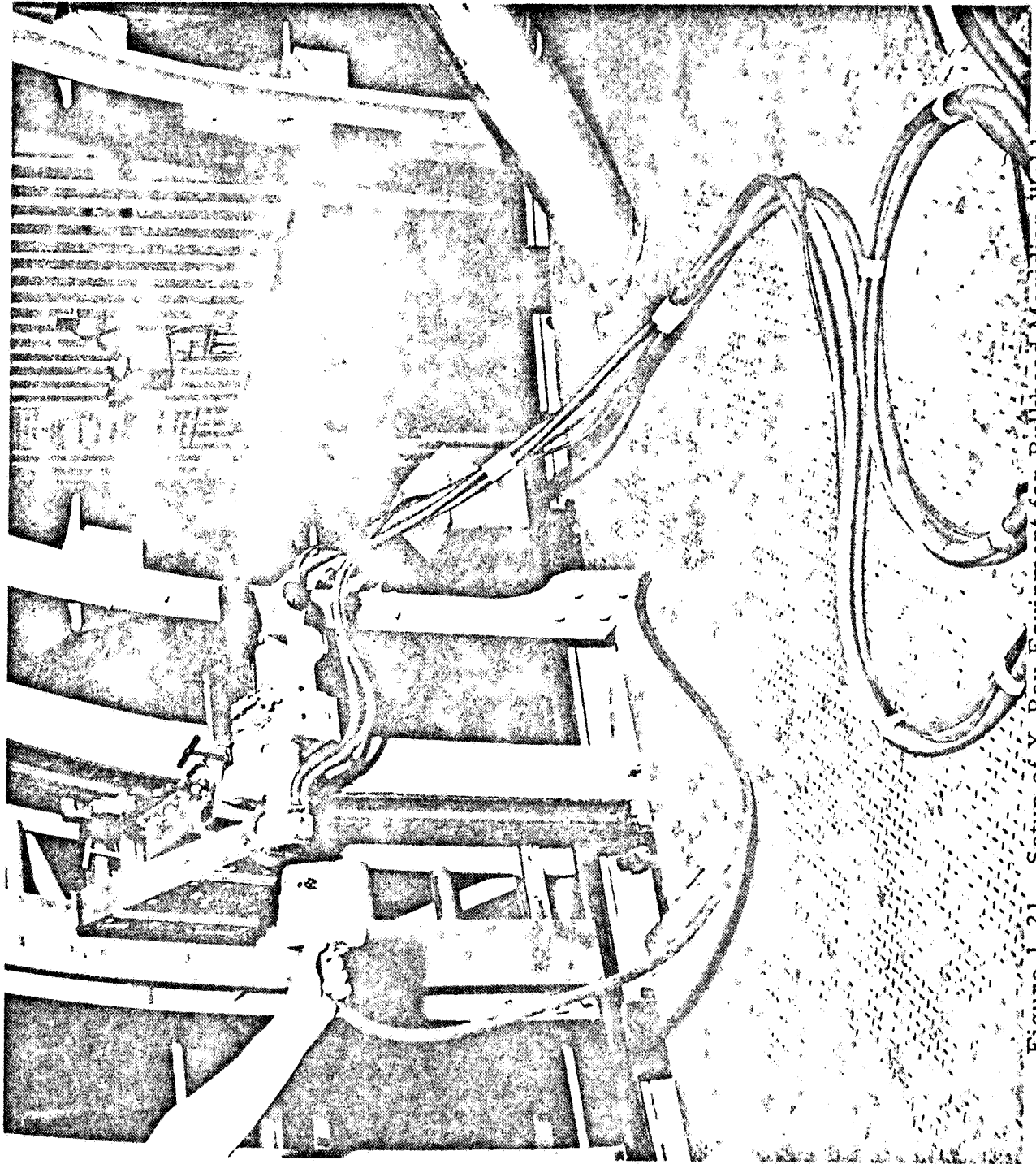


Figure 1-21. Setup of X-Ray Equipment for Bulkhead Meridian Welds

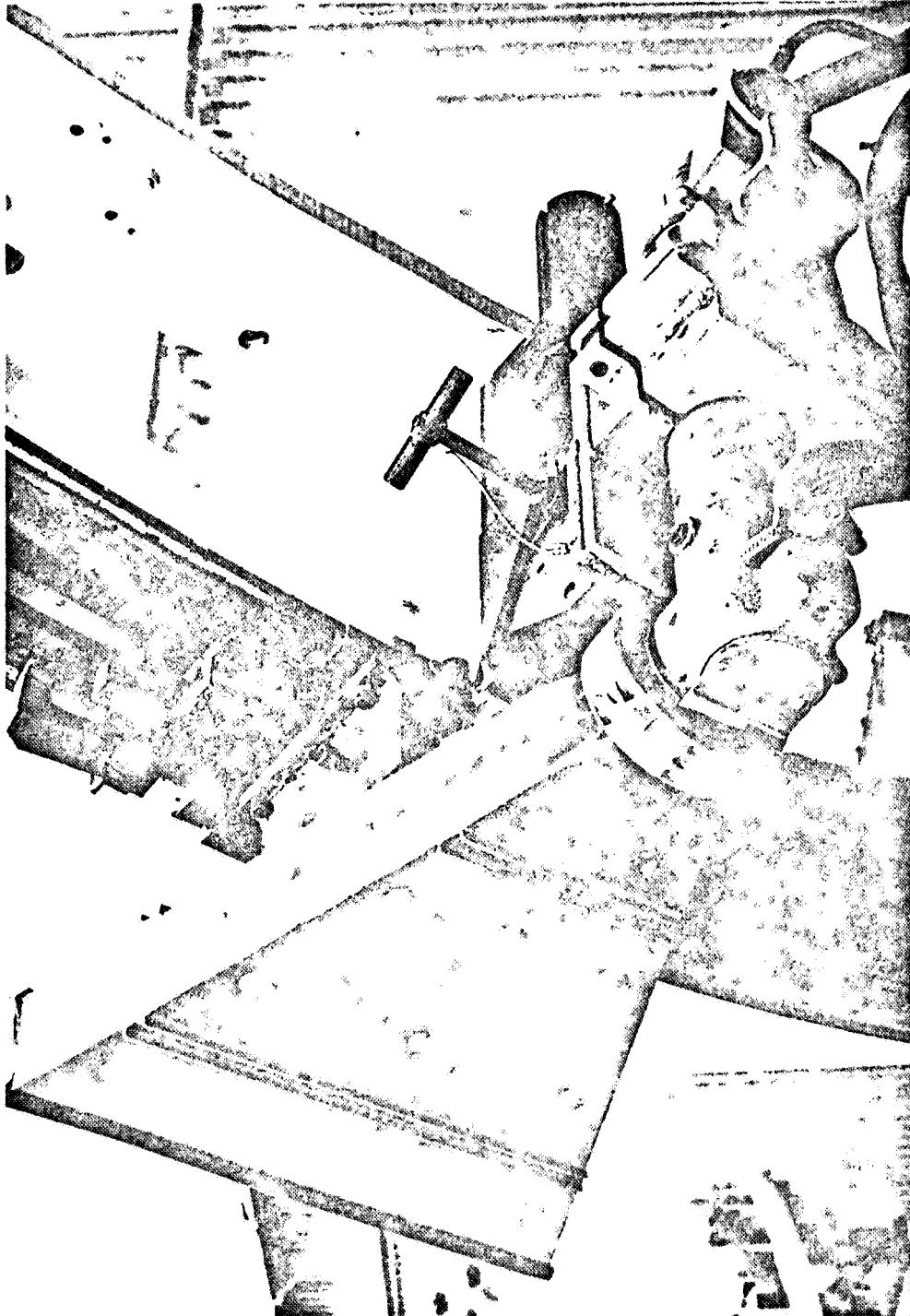


Figure 1-22. X-Ray Tubehead Secured Into Skate Fixture

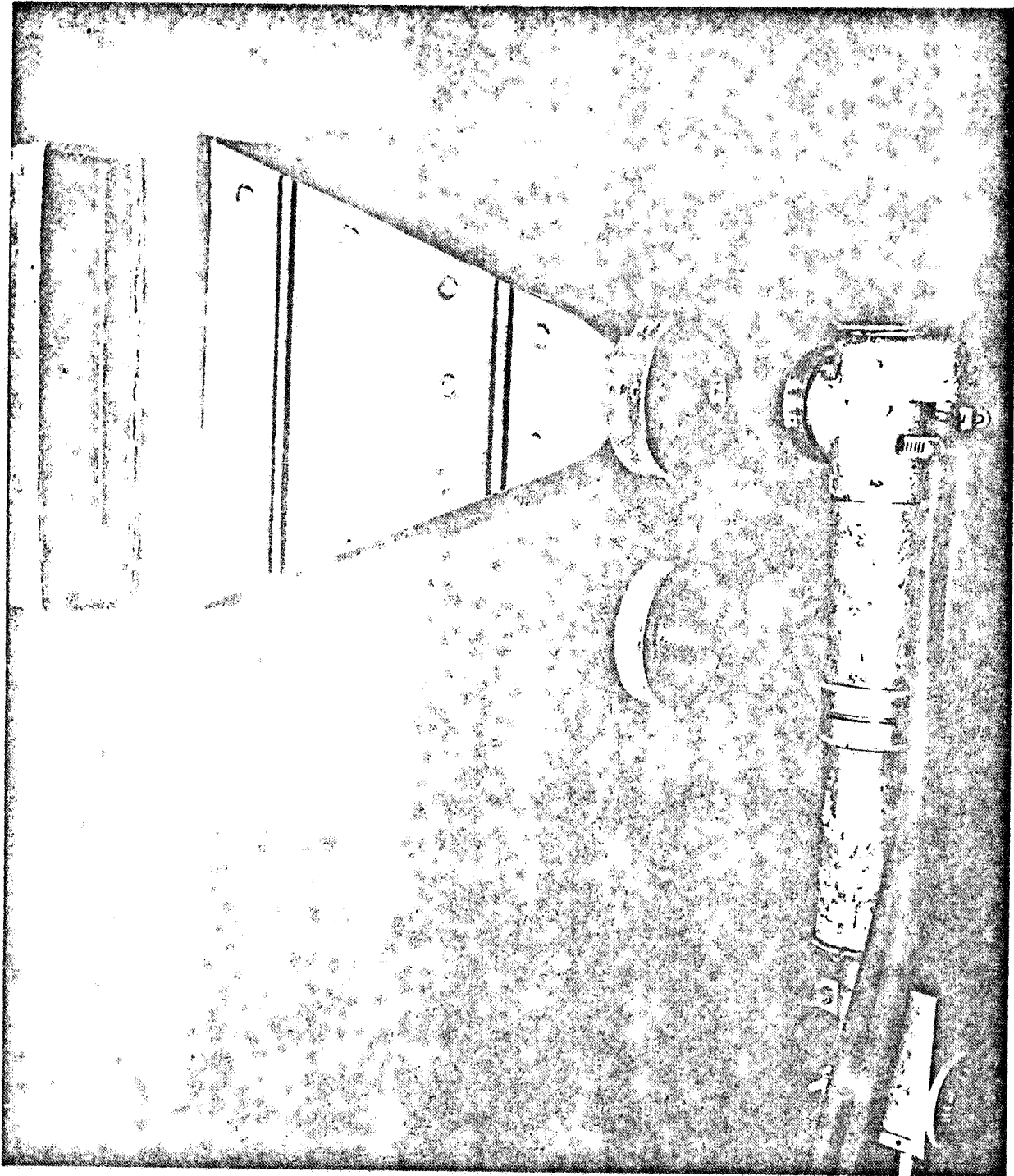


Figure 1-23. X-Ray Tubehead and Shielding Devices



5. Remove the exposed 21-foot strip of X-ray film and replace it with the second unexposed 21-foot strip of film in accordance with the procedures defined under "Placement of X-ray Film"
6. Repeat Steps 1 through 4, exposing the alternate odd-numbered views not previously exposed.
7. Deactivate the X-ray machine and remove the key.
8. Install the collimator cover or remove the collimator and replace the lead plug on the tubehead.
9. Remove the second 21-foot strip of film from the part and process the two strips in the automatic film processor

Procedure for "J" Section Exposures - Forward Facing Sheet Only

NOTE See Figure 1-24 for locations of Views A, B₁, B₂, C, and D.

- A Place the film on the exterior side into the bottom of the throat of the "J" section to expose View "C". Place identification and penetrameter on the inside surface
- B Expose Views B₁ and B₂ by placing the film on the exterior of the bulkhead extending from the bottom edge of the panels to the edge of the outboard leg (View "A"). Identification and penetrameter are placed on the inboard surface
- C Expose View "A" by removing the tubehead from the skate fixture and bringing it to the outboard side of the bulkhead tool. The tubehead is mounted in the telescopic tube support, then secured to the 8EH-0066-21 work platform. The X-ray film is placed behind the outboard leg (View "A") resting on the bottom of the throat of the "J" section. Identification and penetrameter are placed on the outboard surface
- D Expose View "D" by positioning the collimator over the center of the weld and directing the X-ray beam (down) into the throat of the "J" section (Figure 1-25). The X-ray film (1-1/2 inches wide) is inserted through the slot below the throat of the "J" section

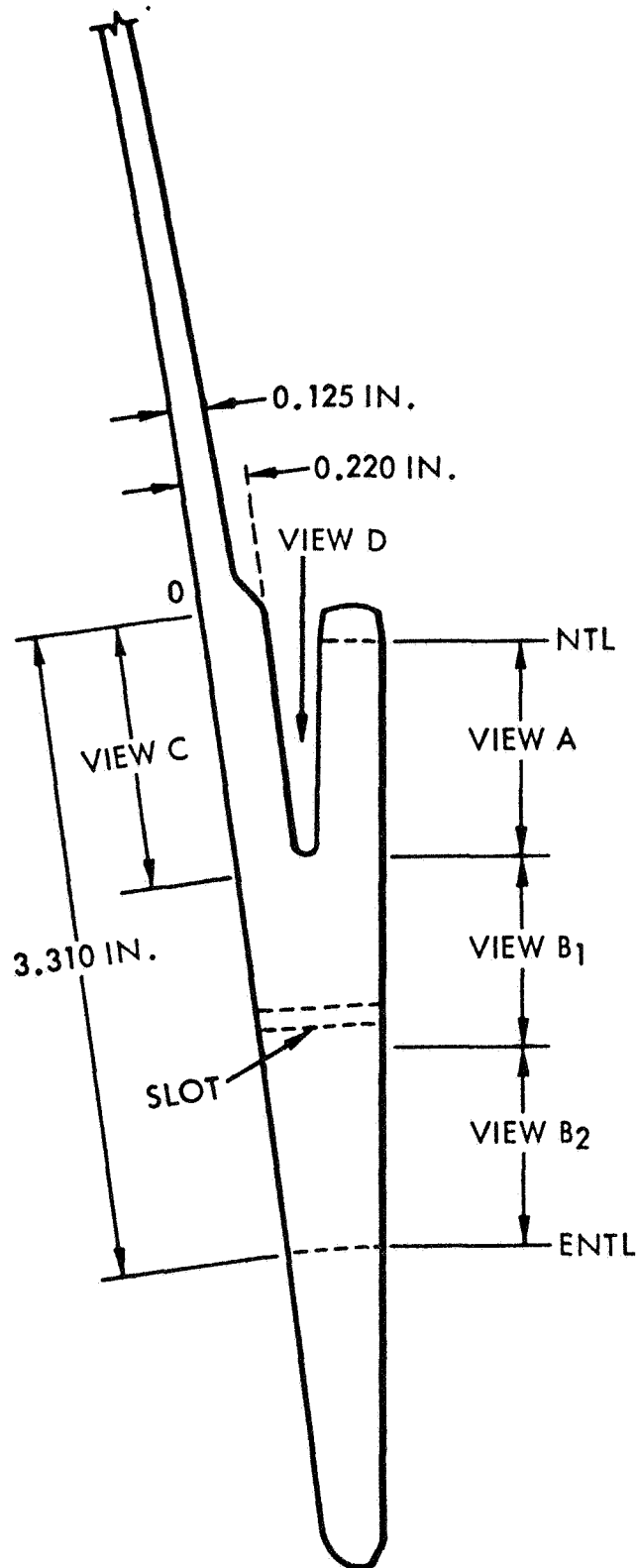


Figure 1-24. "J" Section Configuration

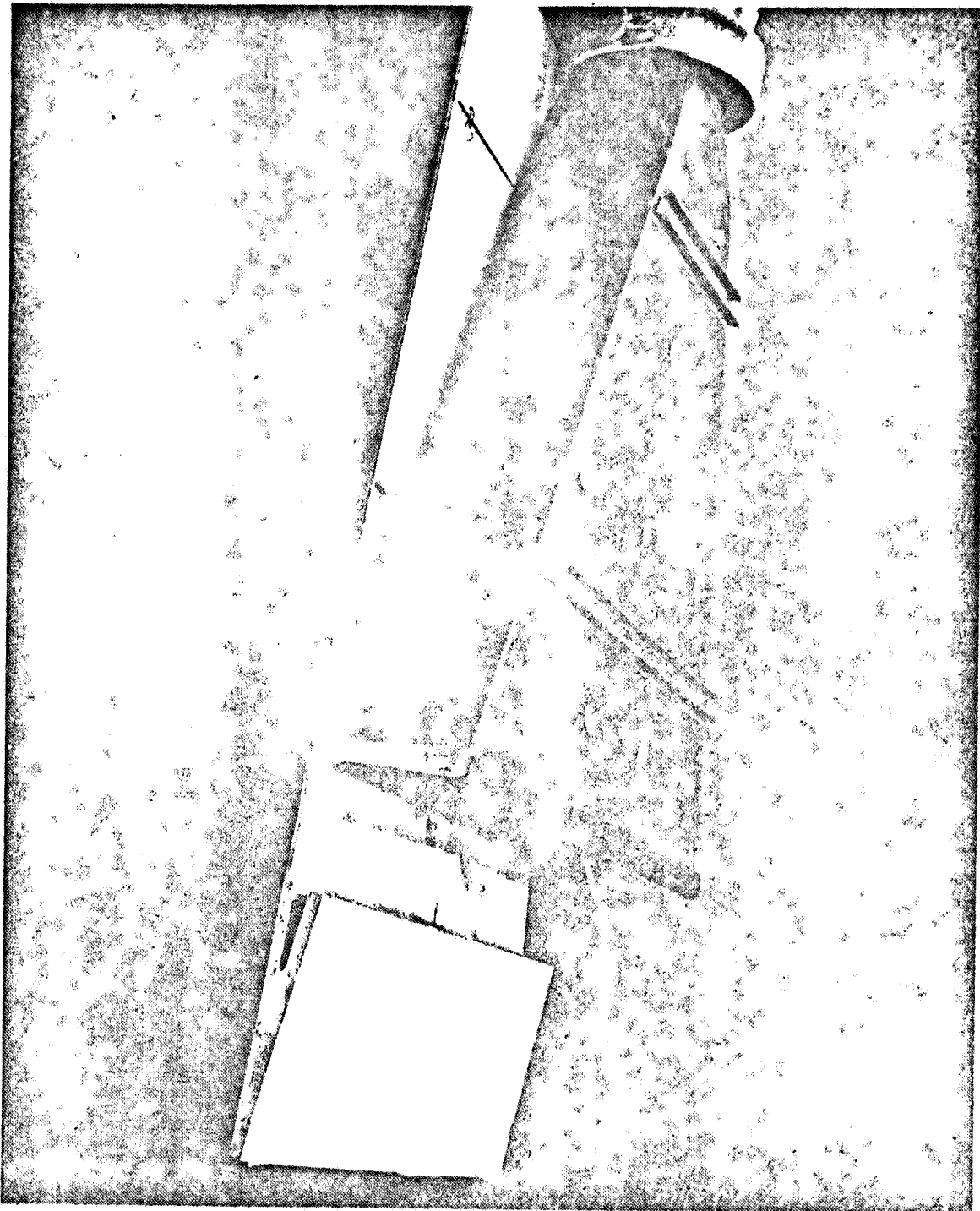


Figure 1-25. Collimator Positioned to Expose View "D"

CAUTION

Radiation safety requirements shall be strictly enforced as outlined in Section 1.2.

1.3.2 CIRCUMFERENTIAL WELDS AFTER FABRICATION

Special Equipment and Materials Required

A. Lead identification markers

1. Alternate individual numbers 1 through 215
 - a. Continuous individual numbers 0 through 124 for the "J" and LO₂ circumferential welds only
2. Position numbers I, II, III, and IV

NOTE: Prepared number belts may be used in lieu of the above.

3. X-ray control number

B. Industrial X-ray film (Kodak type "M") 70 mm

1. Four 28-foot strips for the penetration pass
2. Eight 28-foot strips for the cover pass

C. Two 18-inch collimators

D. X-ray tubehead holding fixtures (two)

NOTE All circumferential welds are radiographically inspected in two phases during fabrication. The initial inspection is made following completion of the penetration pass and is primarily an information-type inspection. The second inspection is made upon completion of the cover pass and any in-process rewelds. These instructions and procedures are detailed separately for each inspection where differences occur.



Procedure for Inspection

- A. Placement of identification markings (Cylinders 1-2, 2-3, 3-4, 4-5, 5-6, and Cylinder 6 to forward LH₂ bulkhead)
 - 1. Place X-ray view identification markers on the outboard surface of the cylinder.
 - 2. Correlate X-ray view numbers or number belt with the odd number LH₂ cylinder vertical stringers (i.e., 1, 3, 5, etc.)
 - 3. Locate view numbers or number belt 1/4 inch to 3/8 inch above the weld edge.
 - 4. Assure that X-ray views will correspond to consecutive odd-numbered stringer locations (i.e., 1-3, 3-5, 5-7, etc.) Stud finders and magnets are used for this purpose.
- B. Placement of identification markings ("J" circumferential weld and LO₂ circumferential girth weld)
 - 1. Place X-ray view identification markings (lead numbers or number belt) on the outboard surface 1/4 inch to 3/8 inch above the weld edge
 - 2. Locate view number '0' at Position I. Position I is etched on the outboard surface of the assembly. (If a numbered belt is used, a Position I mark is also located on the belt.)
 - 3. Establish X-ray views numerically at 10-inch intervals starting from '0' (Position I) and circumventing the entire weld. (View numbers '0' through '124' are required.)
 - 4. Identify Positions I, II, III, and IV with lead numbers at the appropriate locations.
 - 5. Position numbers to read in a clockwise direction, looking forward (left to right facing the weld)
- C. Placement of X-ray film
 - 1. Place four 28-foot strips of X-ray film on the inboard surface of the weld overlapping all ends with each adjacent strip.



D. Setup of X-ray equipment (Figure 1-26)

1. Position two X-ray machines (100 kv) at or near Position I.
2. Attach two X-ray tubehead holding fixtures to the weld skate tracks.
3. Remove the lead protective covers (plugs) and install the collimators.
4. Mount the tubeheads to the holding fixtures (Figure 1-27)
5. Align the collimators with the weld centerline and position the collimators adjacent to each other at Views 1-3 and 3-5 or 0-1 and 1-2, as applicable (penetration pass only)

NOTE: For the cover-pass inspection, the collimators are positioned at alternate views (i. e., 1-2, 3-4 or 1-3, 5-7, etc.)

E. Exposure procedure

1. Determine the material thickness from the thickness chart (all circumferential welds are of constant thickness)
2. Select the proper machine settings from the technique curve
3. The X-ray machine is activated after adherence to all safety procedures.
4. Expose every other view (for cover pass) or every view (for penetration pass) about the entire circumference of the weld
5. Remove the exposed X-ray film and process in the automatic film processor

NOTE: For the cover-pass inspection, remove the exposed X-ray film and replace with four unexposed strips in accordance with Step C

6. Repeat exposure of Procedure E, Steps 1 through 5, exposing the alternate views not previously exposed

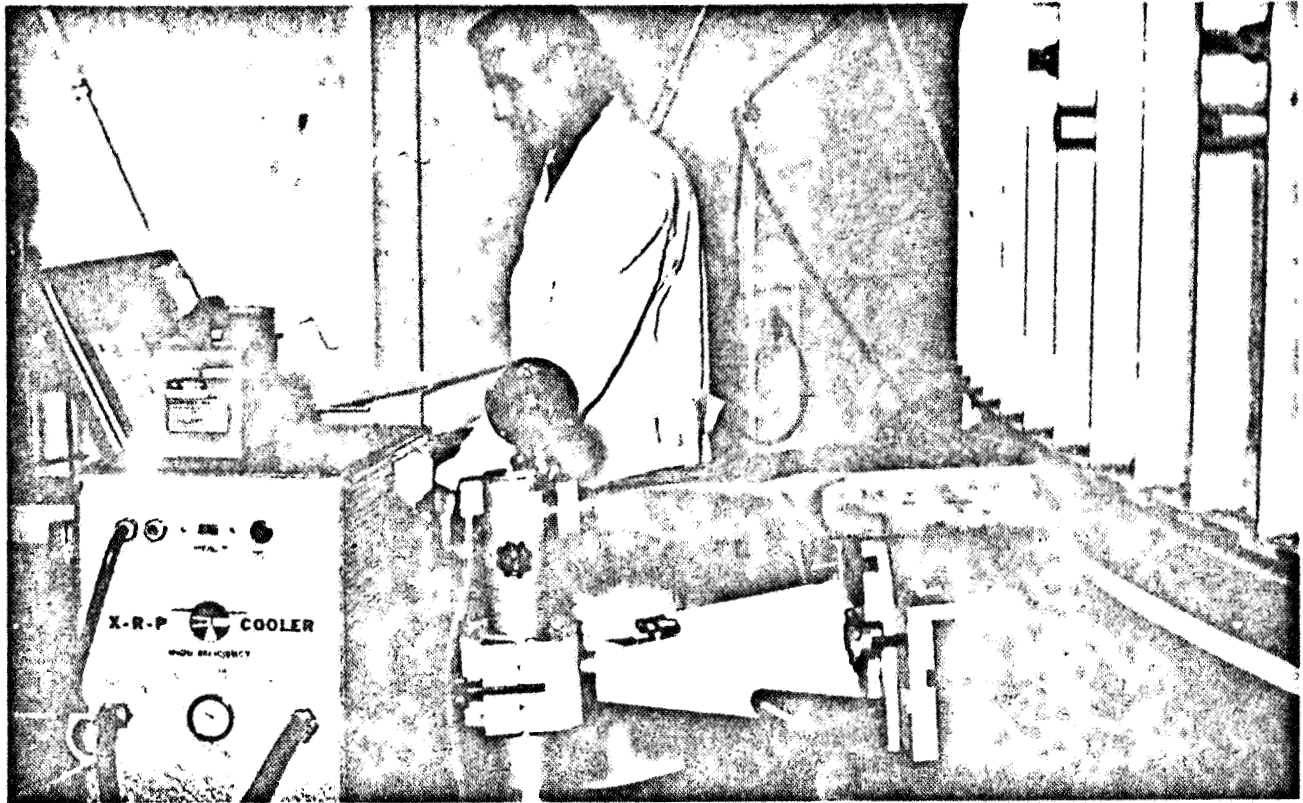


Figure 1-26. Setup of X-Ray Equipment for Circumferential Welds

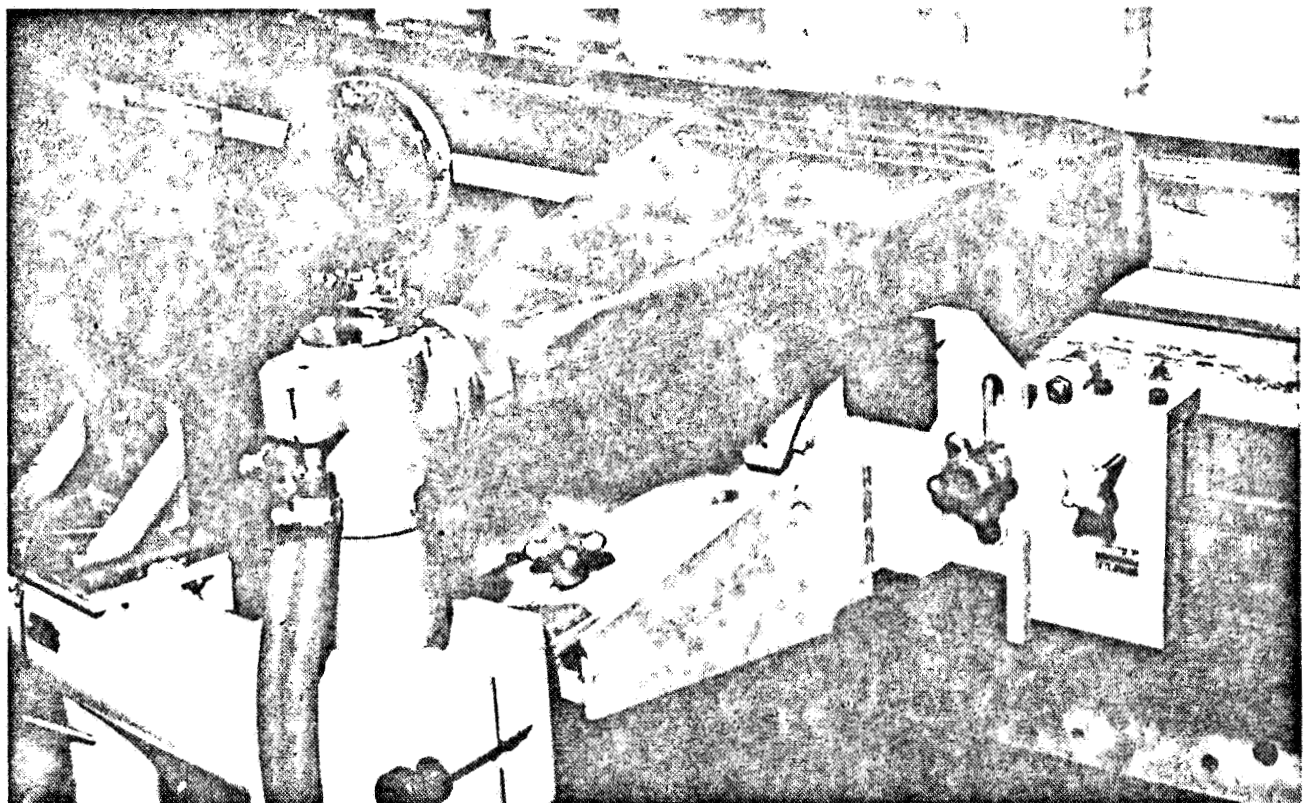


Figure 1-27. Tubehead Mounted to Holding Fixture for Circumferential Welds



7. Deactivate the X-ray machine and remove key.
8. Install the collimator covers or remove the collimators and replace the lead plugs.
9. Remove the exposed X-ray film and process in the automatic film processor.

NOTE: Station 1A (bulkhead building extension) is unique in that the entire tool rotates. This capability is utilized when X-ray inspections are performed on assemblies in this tool to change position of the tubehead locations relative to the welds. The procedure for this tool, with the exception of the X-ray tubehead movement, is identical to the other tooling for the circumferential welds. On this tool the tubehead is held stationary and the assembly is rotated for each separate exposure. On all other tools, the X-ray tubehead is moved along the weld track for each succeeding exposure.

1.3.3 LH₂ CYLINDER VERTICAL WELD SPLICES AFTER FABRICATION

Special Equipment and Materials Required

A. Lead identification markers

1. Top net trimline (TNTL), bottom net trimline (BNTL)
2. Continuous numbers 0 through 10 (numbers 0 through 3 for Cylinder 1 only)

NOTE Prepared number belts may be used in lieu of the above.

3. X-ray control number

B. Industrial X-ray film (Kodak type "M") 70 mm

1. Two strips, 11 feet in length
2. Two strips, 2-1/2 feet in length for Cylinder 1 only

C. Lead vinyl backing strip, 11 feet in length (3 feet in length for Cylinder 1)

D. X-ray tubehead holding fixture

E. "Hi-Boy" lift

NOTE: Cylinder 1 is 28 inches in height, all others are 100 inches in height.

Procedure for Inspection

A. Placement of identification markings

1. Place X-ray view number identification markers on the outboard surface of the cylinder. Numbers or number belts are located on the left-hand side, facing the weld from the outboard side
2. Place View "0" at the bottom net trimline (BNTL) approximately 1/4 inch from the edge of the weld.
3. Place an arrow marker with the identification BNTL on the right-hand side identifying the bottom net trimline .
4. Position view numbers numerically on the left-hand side of the weld starting from the bottom net trimline (BNTL) to the top net trimline (TNTL) in 10-inch increments
5. Place an arrow marker with the identification (TNTL) on the right-hand side, adjacent to the weld identifying the top net trimline

B. Placement of X-ray film and shielding

1. Place one 11-foot strip of X-ray film on the interior (inboard) surface of the weld, taking care to assure that the film is centered over the weld and overlaps the panel at both ends
2. Hang the lead vinyl backup shielding from the top of the cylinder and center over the weld.

C. Setup of X-ray equipment (Figure 1-28)

1. Position the "Hi-Boy" lift adjacent to the outboard surface of the weld.
2. Attach the X-ray tubehead holding fixture to the "Hi-Boy" lift



3. Mount the X-ray tubehead to the holding fixture (Figure 1-29).
4. Remove the lead protective cover (plug) from the tubehead and install the collimator.
5. Align the collimator with the weld centerline and position at View 0-1.

D. Exposure procedure

1. Determine the material thickness from the thickness chart.
2. Select the proper machine settings from the technique chart.
3. The X-ray machine is activated after adherence to all safety procedures
4. Expose every other view (i. e., 0-1, 2-3, etc.) for the entire length of the cylinder weld splice.
5. Remove the lead vinyl backup shield and the exposed strip of film.
6. Replace with the unexposed film strip and replace backup shielding.
7. Repeat exposure of Procedure D, Steps 1 through 4, exposing the alternate views not previously exposed.
8. Deactivate the X-ray machine and remove key
9. Install the collimator cover or remove the collimator and replace the lead plug.
10. Remove the lead vinyl shielding and the exposed strip of X-ray film
11. Process both exposed strips of film in the automatic film processor.

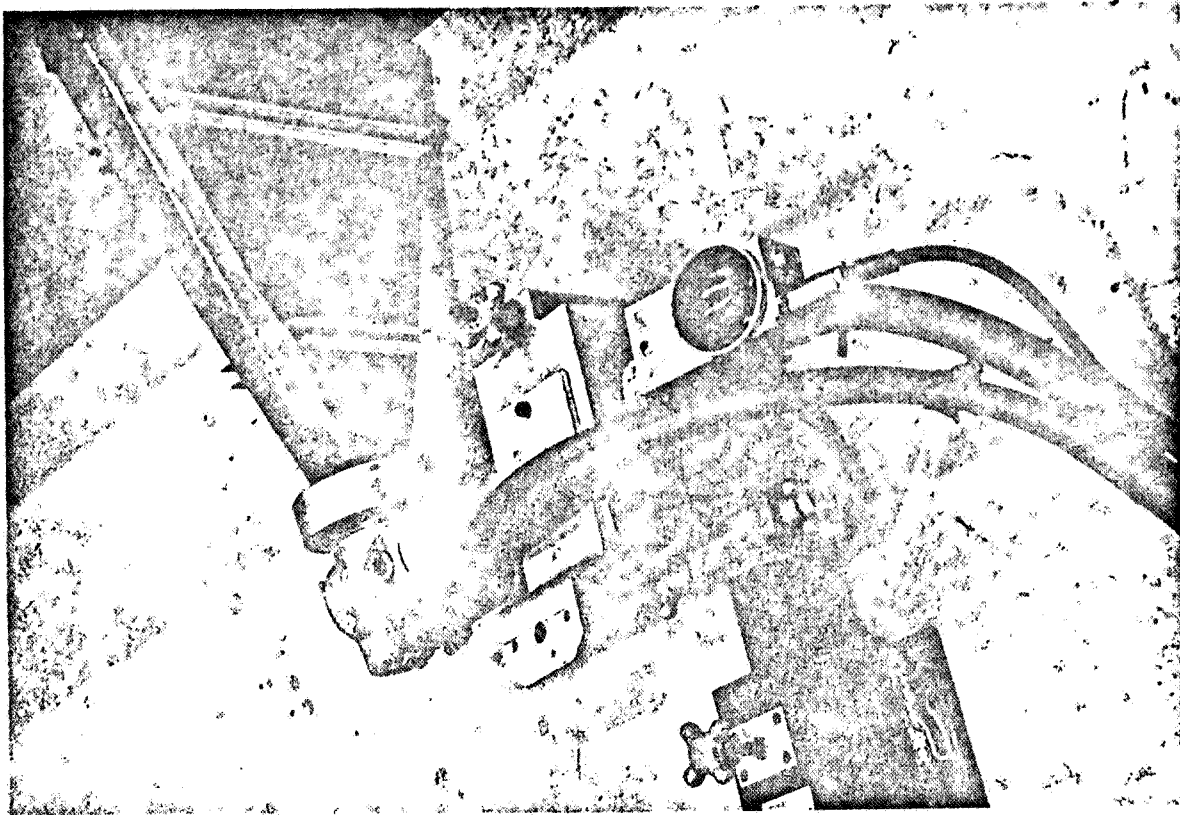


Figure 1-29. X-Ray Tubehead and
Holding Fixture for Cylinder
Splice Welds

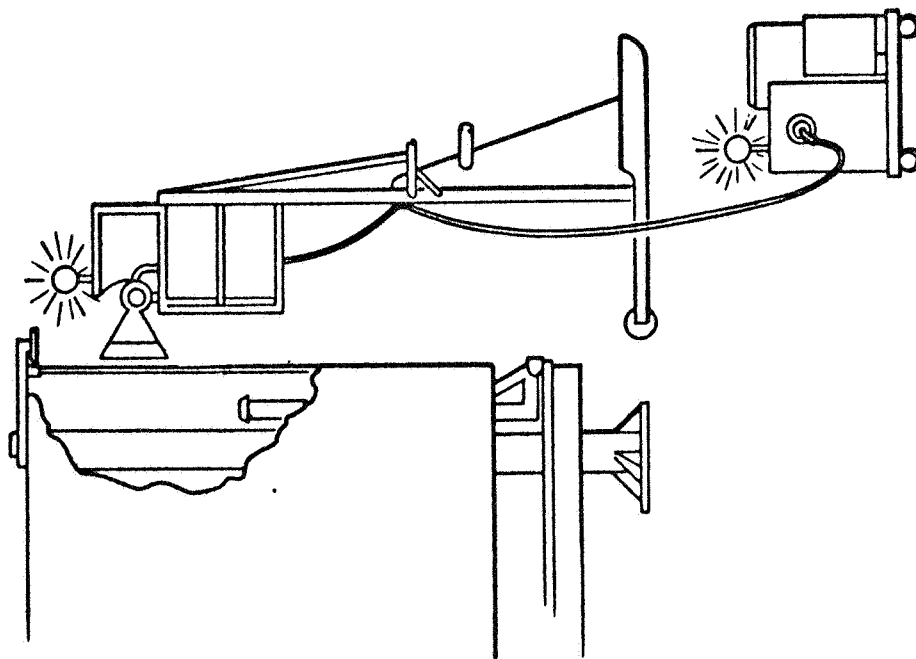


Figure 1-28. X-Ray Equipment Setup for Cylinder
Splice Welds



1.3.4 BULKHEAD DOLLAR WELDS AFTER FABRICATION

Special Equipment and Materials Required

- A. Lead identification markers
 - 1. Letters "A" through "L" and continuous numbers 0 through 15 (continuous numbers 0 through 35 for the aft LO₂ bulkhead only)
 - 2. X-ray control number
- B. Industrial X-ray film (Kodak type "M") 70 mm (16 strips 14 inches in length, 36 strips 14 inches in length for the aft LO₂ bulkhead only)
- C. X-ray tubehead holding fixture
- D. Lead vinyl backup shielding for the aft LO₂ bulkhead (in-tool lead backup shielding is incorporated on the T72-00077 tool for all other bulkheads)

Procedure for Inspection (Aft Facing Sheet Forward Facing Sheet and Forward LH₂ Bulkheads)

- A. Placement of identification markings
 - 1. Place X-ray view number identifications on the outboard surface of the bulkhead. Numbers are to be located adjacent to the weld on the dollar-section side of the bulkhead.
 - 2. Place View 0 at Position I (Position I location is etched on assembly).
 - 3. Position the remaining numbers numerically in 10-inch increments in a counterclockwise direction when viewed from the outboard side.
 - 4. Identify each meridian weld by its letter designation. The letter identification is placed on the bulkhead side of the weld adjacent to the meridian/dollar weld junction.

B. Placement of X-ray film

1. Place eight strips of X-ray film, 14 inches in length, on the inboard surface at alternate X-ray view locations (i. e., 0-1, 2-3 etc.). Special care is required to assure that the weld area is completely covered by the X-ray film.

C. Setup of X-ray equipment (Figure 1-30)

1. Contact Move Control to have the X-ray machine placed by the riggers in the location provided on top of the T72-00077 tool.
2. Attach the X-ray tubehead holding fixture to the weld skate track.
3. Remove the lead protective cover (plug) from the tubehead and install the collimator.
4. Mount the X-ray tubehead to the holding fixture.
5. Align the collimator with the weld centerline and position at View 0-1.

D. Exposure procedure

1. Determine the material thickness from the thickness chart (each dollar weld is of constant thickness).
2. Select the proper machine settings from the technique chart.
3. The X-ray machine is activated after adherence to all safety procedures.
4. Expose every other view (0-1, 2-3, etc) around the dollar weld.
5. Remove the exposed X-ray film and replace the remaining eight unexposed strips of film at the alternate X-ray positions.
6. Repeat Procedure D, Steps 1 through 4, exposing the alternate views not previously exposed.
7. Deactivate the X-ray machine and remove the key.
8. Install the collimator cover or remove the collimator and replace the lead plug.



Figure 1-30. Setup of X-Ray Equipment for Bulkhead Dollar Welds

9. Remove the exposed X-ray film and process all film in the automatic film processor.

Procedure for Inspection of Aft LO₂ Bulkhead Dollar Weld (See Note*)

A. Placement of identification markings

1. Place X-ray view number identification markers on the inside surface of the bulkhead. Base of the numbers are to be placed adjacent to the weld and upside down on the dollar-section side of the bulkhead.
2. Place view number "0" at Position I and the remaining numbers numerically in a clockwise direction at 10-inch increments.
3. Identify meridian welds by their letter designations at each intersection. Letter identifications are placed upside down on the gore side of the bulkhead adjacent to the weld junction.

B. Placement of X-ray film

1. Place 18 strips of X-ray film 14 inches in length on the out-board surface at alternate X-ray view locations (i. e. , 0-1, 2-3, 4-5).
2. Place lead vinyl backup shielding over the film areas to be exposed.

C. Setup of X-ray equipment

1. Attach the X-ray tubehead holding fixture to the weld skate track.
2. Remove the lead protective cover and install the collimator
3. Mount the X-ray tubehead to the holding fixture.
4. Align the collimator with the weld centerline and position at View 0-1.

- D. Exposure procedure: Same as item D under "Procedure for Inspection."

*NOTE: The aft LO₂ bulkhead dollar weld is 10 feet in diameter as opposed to 3 feet for the other bulkheads. Additionally, this joint is welded from both sides with the second side (inboard) being welded in the inverted position. The radiographic inspection is performed while the bulkhead is in this position; exposures are made with the tubehead on the inboard side.

1.3.5 BULKHEAD GORE PANEL SUBASSEMBLY WELDS AFTER HYDRO-STATIC TESTING (AFT FACING SHEET AND AFT LO₂ BULKHEAD)

Special Equipment and Materials Required

A. Lead identification markings

1. Continuous numbers 0 through 9 (12 sets)
2. X-ray control numbers (new numbers to be assigned)
3. Letters "A" through "L"

NOTE: These welds are fabricated at the Los Angeles Division, and, therefore, new Space Division X-ray control numbers are assigned at this time

B. Industrial X-ray film (Kodak type "M") 70 mm

1. One hundred and twenty strips, each 14 inches in length

Procedure for Inspection

A. Placement of identification markings

1. Place X-ray view identification markers on the inboard surface. View number "0" is located at the circumferential/meridian weld intersection of the lower alphabet letter of each meridian.
2. Establish X-ray views at 10-inch increments. The letter designation of each meridian weld is placed at each view number "0" location.



3. View numbers and weld letters are faced outboard and read in a counterclockwise direction (right to left) when viewed from the inboard side of the bulkhead.

B. Placement of X-ray film and shielding

1. Position each 14-inch piece of X-ray film individually at the location to be exposed immediately before each exposure. The area to be exposed is shielded using lead vinyl backing.
2. Remove the previously exposed X-ray film and place an unexposed piece at the next view to be X-rayed along with the lead vinyl shielding. This procedure is continued about the entire circumference of the bulkhead.

NOTE: In addition to the normal X-ray views, an exposure is made straight-in at each circumferential/meridian weld intersection.

C. Setup of X-ray equipment

NOTE The bulkheads are normally positioned on the ultrasonic inspection tool for the post-hydrostat inspections. The rotational capability of the tool is utilized to facilitate these inspections.

1. Place special tubeholder tool on the inboard transducer carriage assembly (See Figure 1-31)

NOTE A special counterbalance is installed to offset the weight difference of the X-ray tube and collimator to the ultrasonic transducer and squirter assembly to prevent damage to the motors

2. Mount the X-ray tubehead to the holding fixture.
3. Remove the lead protective cover (plug) from the tubehead emission point and install the collimator.
4. Position the collimator at the center of the horizontal/meridian weld intersection.

D. Exposure procedure

1. Determine the material thickness from the material thickness chart. (All of these welds are of constant thickness)

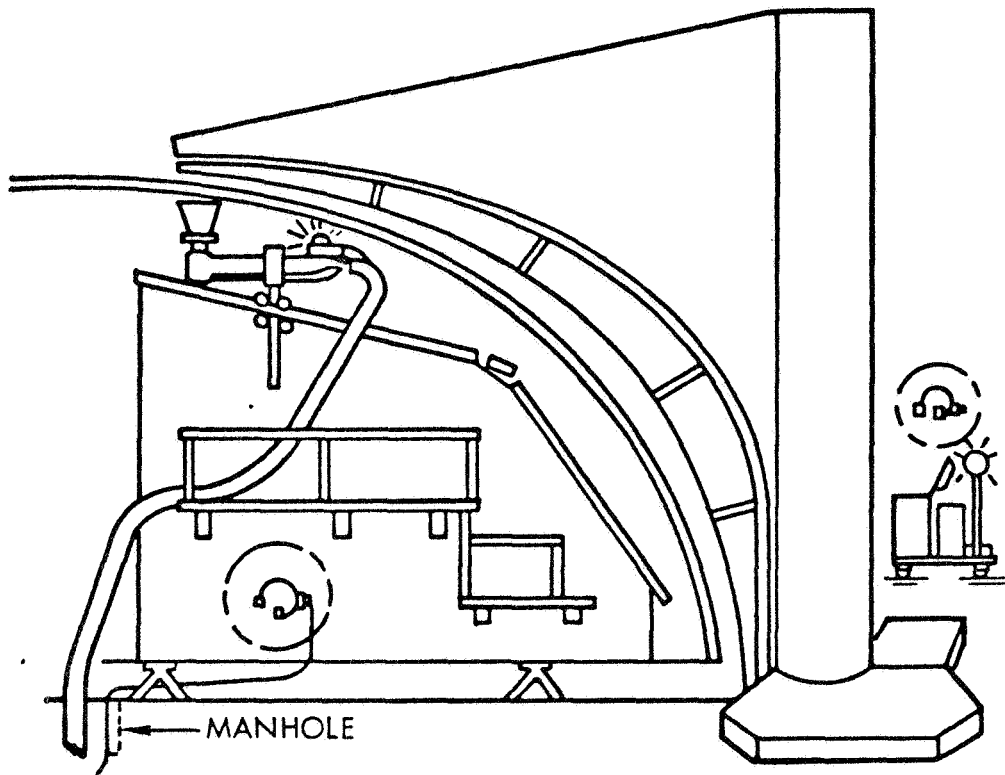


Figure 1-31. X-Ray Equipment Setup – Post-Hydrostatic Inspection

2. Select the proper machine settings from the technique curve.
3. The X-ray machine is activated after adherence to all safety procedures.
4. Remove the exposed X-ray film and place an unexposed film on the next succeeding view.
5. Rotate the bulkhead to the next view location.
6. Position lead vinyl backup shielding on the area to be exposed.
7. Repeat Steps 3 through 5 until the entire weld has been X-rayed.
8. Process the exposed film progressively during the exposures.
9. Deactivate the X-ray machine and remove the key.
10. Remove the collimator and place lead safety plug in the tubehead opening.

1.3.6 BULKHEAD MERIDIAN WELDS AFTER HYDROSTATIC TESTING

Equipment and Materials Required

A. Forward LH₂ bulkhead

1. Lead identification markers

- a. Individual numbers 0 through 18 (12 sets)
- b. Letters ENTL (12 sets)

NOTE: Prepared number belts may be used in lieu of the above.

- c. X-ray control numbers (originally assigned numbers are used except the letters PH are added to identify the film)

- 2. Industrial X-ray film (Kodak type "M") 70 mm (216 strips, each 14 inches in length)

B Aft facing sheet

1. Lead identification markers

- a. Continuous numbers 0 through 24 (12 sets)
- b. Letters ENTL (12 sets)

NOTE: Prepared number belts may be used in lieu of the above

- c. X-ray control numbers (originally assigned numbers are used with letters PH added)

- 2. Industrial X-ray film (Kodak type "M") 70 mm (288 strips, each 14 inches in length)

C Aft LO₂ bulkhead

1. Lead identification markers

- a. Continuous numbers 0 through 21 (12 sets)



b. Letters ENTL (12 sets)

NOTE: Prepared number belts may be used in lieu of the above.

c. X-ray control numbers (originally assigned numbers are used with letters PH added)

2. Industrial X-ray film (Kodak type "M") 70 mm (252 strips, each 14 inches in length)

Procedure for Inspection

A. Placement of identification markings

1. Place X-ray view number identifications on the inside surface of the bulkhead. Numbers are located on the left-hand side, facing the weld from the inboard side.
2. Place View '0' at the equatorial net trimline (ENTL)
3. Place an arrow marker with the identification ENTL on the righthand side adjacent to the weld identifying the equatorial net trimline.
4. Position view numbers numerically in 10-inch increments on the left-hand side of the weld starting from the equatorial net trimline and ending at the dollar weld.

NOTE: At this time the forward LH₂ bulkhead is only X-ray inspected 172 inches from the equatorial net trimline toward the apex (dollar).

B. Placement of X-ray film

1. Place one 14-inch strip of film at View 0-1 on each meridian weld on the outboard surface.
2. Repeat placement of X-ray film for subsequent exposures in the same manner at the next view location when all View 0-1 exposures have been made.

C. Setup of X-ray equipment

NOTE: The bulkheads are normally positioned on the ultrasonic inspection tool for the post-hydrostat inspections. The rotational capability of the tool is utilized to facilitate these inspections.

1. Place special tubeholder tool on the inboard transducer carriage assembly. (See Figure 1-31.)

NOTE: A special counterbalance is installed to offset the weight difference of the X-ray tube and collimator to the ultrasonic transducer and squirter assembly to prevent damage to the drive motors.

2. Mount the X-ray tubehead to the holding fixture.
3. Remove the lead protective cover (plug) from the tubehead emission point and install the collimator.
4. Position the collimator at the View 0-1 location of the meridian weld and center over the weld area.
5. Position the outboard boom (to which the backup shielding is attached), directly in front of the weld.

D. Exposure procedure

1. Determine the material thickness from the material thickness chart.
2. Select the proper machine settings from the technique curve.
3. The X-ray machine is activated after adherence to all safety procedures.
4. Expose View 0-1 on each meridian weld by rotating the bulkhead after each exposure.
5. Remove the exposed X-ray film and replace with an unexposed film on each meridian weld at View 1-2.
6. Repeat Steps 1 through 5 and continue the same procedure until all areas required to be inspected have been X-rayed.



7. Process the exposed X-ray film after each series of X-ray views have been completed.
8. Deactivate the X-ray machine and remove the key.
9. Remove the collimator and replace the lead plug.

1.3.7 AFT FACING SHEET AND AFT LO₂ BULKHEAD DOLLAR WELDS AFTER HYDROSTATIC TESTING

Special Equipment and Materials Required

- A Lead identification markings
 1. Continuous individual numbers 0 through 35 and letters 'A' through 'L' for the aft LO₂ bulkhead
 2. Continuous individual numbers 0 through 15 and letters 'A' through 'L' for the forward LH₂ bulkhead
- B Industrial X-ray film (Kodak type 'M') 70 mm
 1. Thirty-six strips 14 inches in length for the aft LO₂ bulkhead
 2. Sixteen strips 14 inches in length for the forward LH₂ bulkhead
- C X-ray tubehead holding fixture
- D Lead vinyl backup shielding

Procedure for Inspection

- A. Placement of identification markings
 - 1 Aft facing sheet
 - a Place X-ray view number identifications on the inboard surface of the bulkhead. Numbers are to be located adjacent to the weld on the dollar section side of the bulkhead
 - b. Place view number '0' at Position I (Position I location is etched on the assembly).



- c. Position the remaining numbers numerically in 10-inch increments in a clockwise direction when viewed from the inboard surface.
- d. Identify each meridian weld by its letter designation. The letter designation is placed on the bulkhead side of the weld adjacent to the meridian/dollar weld junction.

2. Aft LO₂ bulkhead

- a. Place X-ray view number identifications on the inboard surface of the bulkhead. Base of numbers are placed adjacent to the weld and upside down on the dollar-section side of the bulkhead.
- b. Place view number "0" at Position I, which is etched on the assembly, and the other numbers numerically in a clockwise direction at 10-inch increments.
- c. Identify meridian welds by their letter designation at each intersection. Letter identifications are placed upside down on the gore side of the bulkhead adjacent to the weld junction.

B. Placement of film and shielding

1. Place strips of X-ray film, 14 inches in length, on the outboard surface at alternate view locations (i. e., 0-1, 2-3, etc.).

NOTE: Special care is required to assure that the weld is completely covered by the film.

2. Place lead vinyl shielding over each film covering the area to be exposed.

C. Setup of X-ray equipment

NOTE: The bulkheads are normally positioned on the ultrasonic inspection tool for the post-hydrostat inspections. The rotational capability of the tool helps facilitate these inspections.

1. Place the special tubeholder on the inboard transducer carriage assembly. (See Figure 1-31.)

NOTE: A special counterbalance is installed to offset the weight difference of the X-ray tube and collimator to the ultrasonic transducer and squirter assembly to prevent damage to the drive motors.



2. Mount the X-ray tubehead to the holding fixture.
3. Remove the lead protective cover (plug) from the tubehead emission point and install the collimator
4. Position the collimator at the View 0-1 location of the dollar weld and center over the weld area

D. Exposure procedure

1. Determine the material thickness from the material thickness chart.
2. Select the proper machine settings from the technique curve
3. The X-ray machine is activated after adherence to all safety procedures.
4. Expose successive alternate views by rotating the bulkhead
5. Remove the exposed X-ray film and replace with an unexposed film on the views not previously exposed
6. Repeat Steps 1 through 5 and continue the same procedure until all areas required to be inspected have been X-rayed.
7. Process the exposed X-ray film after each series of X-ray views have been completed
8. Deactivate the X-ray machine and remove the key.
9. Remove the collimator and replace the lead plug

1.3.8 LO₂ TANK GIRTH WELD AFTER PNEUMATIC TESTING

Special Equipment and Materials Required

A Lead identification markers

1. Continuous individual numbers 0 through 124
2. Position numbers, I, II, III, and IV

NOTE. Prepared number belts may be used in lieu of the above



3. X-rayed control number (originally assigned control number is used)
- B. Industrial X-ray film (Kodak type "M") 70 mm (8 strips, each 28 feet in length)
- C. Two 18-inch collimators
- D. Two X-ray machines (100 kv)
- E. X-ray tubehead skate and holding fixture (Tool No. T7204758)

Procedure for Inspection

- A. Placement of identification markings
 1. Place X-ray view markers (lead numbers or prepared number belt) on the outboard surface 1/4 inch to 3/8 inch above the weld.
 2. Locate view No. "0" at Position I.
 3. Establish X-ray views numerically at 10-inch intervals starting at "0" (Position I) and encircling the entire weld
 4. Position numbers to read in a clockwise direction, looking forward (left to right facing the weld)
 5. Place numbers identifying Positions I, II, III, and IV 1/4 inch to 3/8 inch above the weld at the appropriate locations
- B. Placement of X-ray film
 1. Place four 28-foot strips of X-ray film on the inboard surface of the weld, overlapping all ends with each adjacent strip
- C. Setup of X-ray equipment (Figure 1-32)
 1. Attach the two sections of portable skate track (Tool No. T7204758) to the aft skirt, which has been lowered to perform this inspection. The skate tracks should be positioned adjacent to each other
 2. Mount the X-ray tubehead holding fixtures to the skate track.

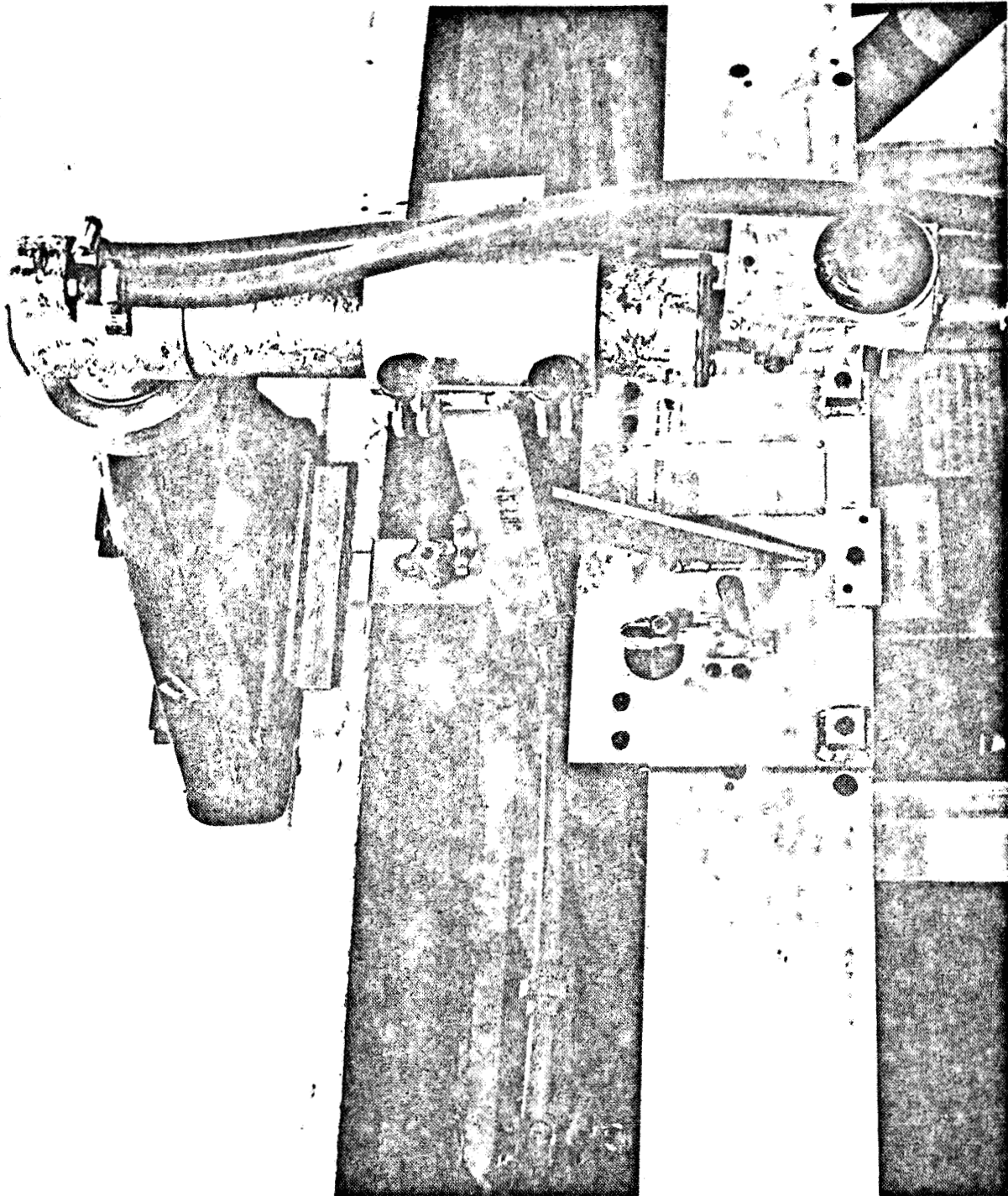


Figure 1-32. Setup of X-Ray Equipment for LO₂ Girth Weld After Pneumatic Testing



3. Remove the lead protective covers (plugs) and install the collimators.
4. Mount the tubeheads to the holding fixtures.
5. Align the collimators with the weld centerline and position the collimators at alternate views (i. e., 1-2, 3-4, etc.).

D. Exposure procedure

1. Determine the material thickness from the thickness chart (the weld is of constant thickness).
2. Select the proper machine settings from the technique curve
3. The X-ray machine is activated after adherence to all safety procedures.
4. Remove and reposition the first section of the skate track in front of and adjacent to the second section when the skate has passed from one track section onto the second. This procedure is repeated about the entire weld.
5. Remove the exposed X-ray film and process in the automatic film processor.
6. Replace with four unexposed 28-foot strips of film.
- 7 Repeat Steps 1 through 4 exposing the alternate views not previously exposed.
8. Deactivate the X-ray machine and remove the key
9. Install the collimator cover or remove the collimators and replace the lead plugs.
- 10 Remove the exposed X-ray film and process in the automatic film processor.

1.3.9 FORWARD LH₂ BULKHEAD MERIDIAN AND DOLLAR WELDS
AFTER PNEUMATIC TESTING

Special Equipment and Materials Required

A. Lead identification markings



1. Continuous individual numbers 17 through 24 (12 sets required)
 2. Continuous individual numbers 0 through 15 (one set)
 3. Letters "A" through "L"
 4. X-ray control numbers (originally assigned numbers are used)
- B. Industrial X-ray film (Kodak type "M") 70 mm
1. Twenty-four strips 6-1/2 feet in length
 2. Sixteen strips 14 inches in length
- C. Tripod (vacuum) tubeholder, Tool No. R976572
- D. Lead vinyl shielding

NOTE: The post-pneumatic radiographic inspection of the LH₂ bulkhead is performed with the vehicle in an inverted position (Station V).

Procedure for Inspection

- A. Placement of identification markings (meridian welds)
1. Place view numbers or number belts adjacent to the meridian welds on the left-hand inboard surface when facing the dollar weld from the inboard side
 2. Establish view number locations the same as identified following initial fabrication (in 10-inch increments from the equator trimline).
- NOTE X-ray views 17 through 24 are the only areas to be inspected at this time.
- B. Placement of identification markings (dollar weld)
1. Place X-ray view numbers on the inboard surface adjacent to the weld on the dollar side
 2. Position numbers to run numerically in a clockwise direction.



3. Locate view number "0" at Position I with subsequent numbers placed at 10-inch intervals.
4. Identify meridian welds by their letter designation on the gore panel side adjacent to the weld junction.

C. Placement of X-ray film (meridian welds)

1. Determine the exact location of the meridian welds on the outboard surface with the use of magnets and stud finders

NOTE: Outboard surface is insulated

2. Place a 6-1/2-foot strip of X-ray film over each of the 12 meridian welds on the outboard surface

D. Placement of X-ray film (dollar weld) - Place eight 14-inch strips of X-ray film on the outboard surface at alternate X-ray view locations (i. e. , 0-1, 2-3, etc.). Special care is required to assure that the weld area is completely covered by the X-ray film

E. Setup of X-ray equipment

1. Place the tripod (vacuum) tube holder (Tool No. R976572) on the inboard side of the LH₂ bulkhead (Figure 1-33)
2. Position at View 17-18 on "A" meridian weld
3. Insert the X-ray tubehead through the opening in the center of the dollar section and mount the tubehead to the tube holder
4. Remove the lead protective cover (plug) and install the collimator
5. Align the collimator with the weld centerline at View 17-18 and adjust to a position perpendicular to the weld

F. Exposure technique

1. Determine the material thickness from the thickness chart
2. Select the proper machine settings from the technique curve
3. The X-ray machine is activated after adherence to all safety procedures.

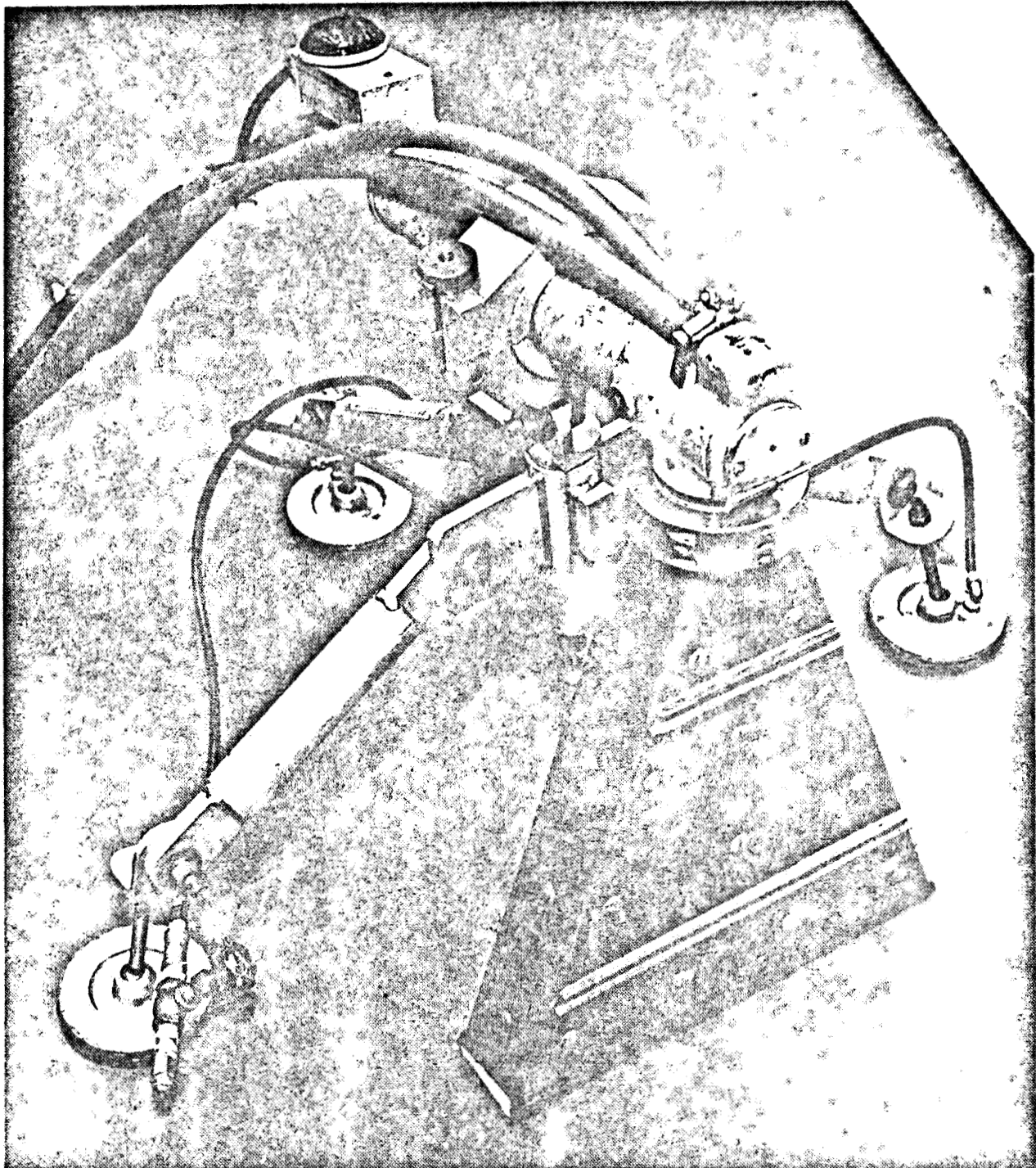


Figure 1-33. Tripod Tube Holder for Inboard Side of LH₂ Bulkhead After Pneumatic Testing

4. Move the tubehead holding fixture to the next alternate view after making the exposure. Continue this process to the end of the weld.
5. Move the tubehead and holding fixture to the next meridian weld ("B") and repeat the process until all meridian welds have been exposed.
6. Remove all the exposed film and replace with unexposed strips of X-ray film.
7. Repeat Steps 1 through 5, exposing the alternate views not previously exposed
8. Remove and process the X-ray film
9. Position the tubehead and holding fixture at View 0-1 on the dollar weld.
10. Expose alternate views in the same manner described in Steps 1 through 8
11. Deactivate the X-ray machine and remove the key
12. Install the collimator cover or remove collimator and replace lead plug.
13. Remove and process X-ray film.

1.3.10 LH₂ TANK CIRCUMFERENTIAL WELDS AFTER PNEUMATIC TESTING

Equipment and Materials Required

A. Lead identification markers

1. Alternate individual numbers 1 through 215 (five sets)

NOTE Prepared number belts may be used in lieu of the above except for Cylinder 1 to Cylinder 2 weld.

2. X-ray control numbers (use original control numbers assigned after fabrication)

B. Industrial X-ray film (Kodak type "M") 70 mm (540 pieces, 14 inches in length)



- C. Two 18-inch collimators
- D. Two X-ray machines (100 kv)
- E. X-ray work platform 8EH-5119
- F. Lead vinyl shielding

- NOTE: 1. This inspection is performed with the vehicle in a horizontal position located on a vehicle transporter.
2. The "J" circumferential weld is not inspected following pneumatic testing. The Cylinder 6 to the forward LH₂ bulkhead weld is radiographically inspected at a later date when the handling skirt is replaced with the flight skirt.

Procedure for Inspection

- A. Placement of identification markings
 - 1. Place X-ray view identification numbers on the inboard surface of the cylinders (except Cylinder 1 to Cylinder 2).
 - 2. Place Cylinder 1 to 2 view numbers on the outboard surface of the tank. Magnets and stud finders are used to positively identify exact stringer locations
 - 3. Identify X-ray views by the odd number LH₂ vertical stringers (i. e., 1, 3, 5, 7, etc.).
 - 4. Position numbers from left to right when viewing from the outboard side (clockwise in flight position)
- B. Placement of X-ray film and shielding
 - 1. Place each 14-inch piece of X-ray film individually in the location to be exposed immediately prior to each exposure.
 - 2. The entire vehicle is rotated on the stage transporter to the next adjacent exposure position after each exposure.
 - 3. Remove the previously exposed X-ray film and place an unexposed piece in the adjacent position.



4. Use lead vinyl backup shielding in the exposure area.

NOTE: Two circumferential welds are exposed simultaneously.

C. Setup of X-ray equipment (Figure 1-34)

1. Position the 8EH-5119 workstand adjacent to Cylinder 5-6 and Cylinder 4-5 circumferential welds.
2. Mount two X-ray tubeheads on the holding fixtures on the workstand.
3. Remove the lead protective covers and install collimators.
4. Align the collimators with the weld centerlines and adjust to a position perpendicular to the welds.
5. Establish view alignment (i. e. , collimator centered between stringers) with the use of magnets and stud finders. Both X-ray machines must be aligned on the same stringer numbers.
6. Position a pointer to the center of an aft skirt stringer (which correlates to LH₂ cylinder stringers) for rotating to the next exposure position.

D. Exposure procedure

1. Determine the material thickness from the material thickness chart.
2. Select the proper machine settings from the technique curve.
3. The X-ray machine is activated after adherence to all safety procedures.
4. Exposure each X-ray view around the entire cylinder. Process the X-ray film intermittently during the process.
5. Move the 8EH-5119 work platform adjacent to Cylinders 3-4 and 2-3 and repeat setup and exposure procedures.

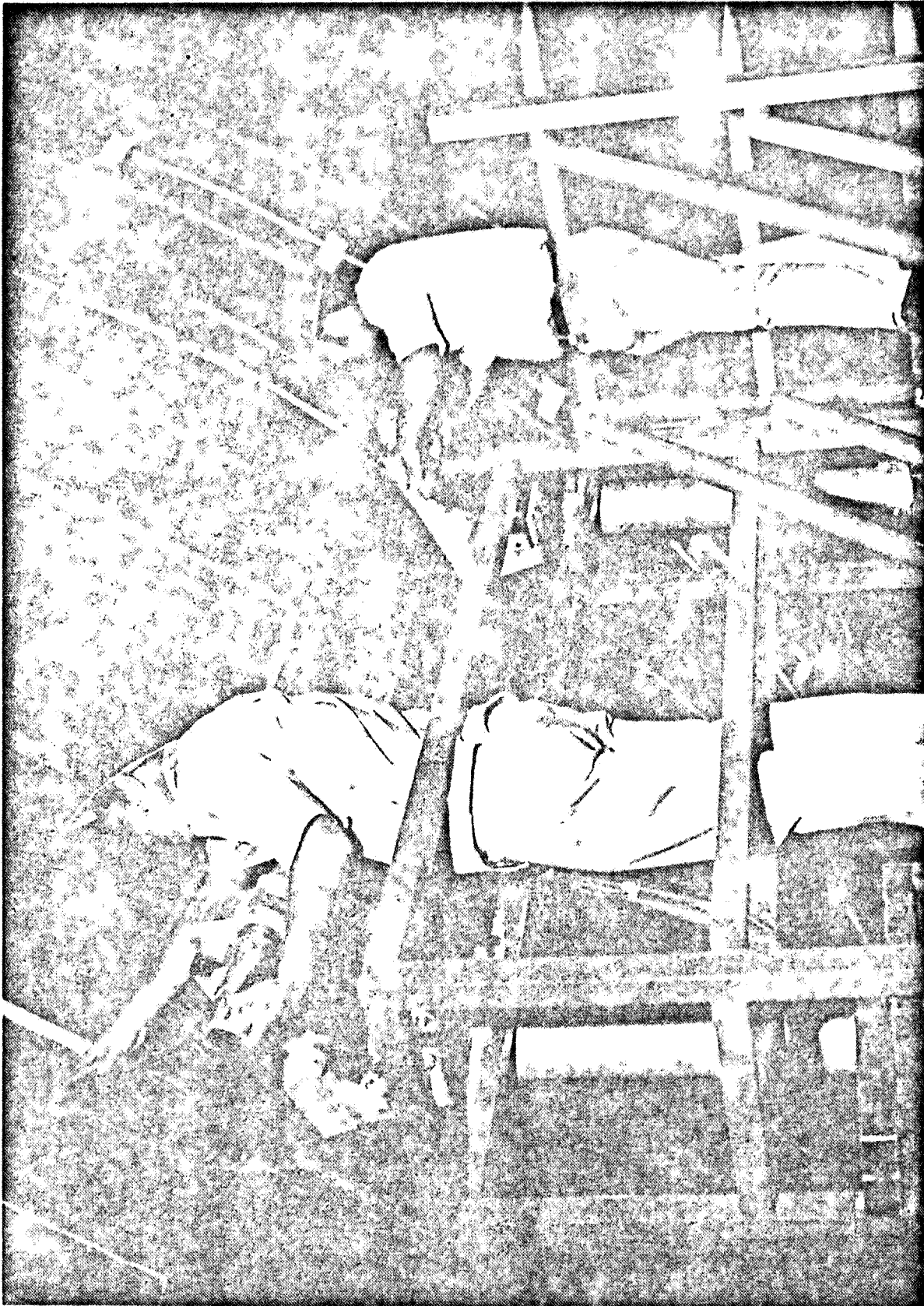


Figure 1-34. Setup of X-Ray Equipment (Circumferential Welds) After
Pneumatic Testing

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6. Move the 8EH-5119 work platform adjacent to Cylinder 1-2. Remove or secure one X-ray tubehead according to safety procedures. Repeat setup and exposure procedures on Cylinder 1-2 welds.
7. Deactivate the X-ray machines and remove the keys.
8. Install the collimator covers or remove the collimators and replace the lead plugs.

NOTE: The procedures for inspecting the Cylinder 6 to the forward LH₂ bulkhead circumferential weld are the same as those previously listed. The weld is not X-rayed immediately after pneumatic testing but after installation of the flight forward skirt. (The flight skirt is considerably thinner than the handling skirt used for handling the stage for pneumatic testing.) Because the inspection is performed through the forward skirt, two exposures (light and dark) are required for each view.

1.3.11 VERTICAL (SPlice) WELDS AFTER PNEUMATIC TESTING

Equipment and Materials Required

A. Lead identification markers

1. Continuous individual numbers 0 through 9 (20 sets)
2. Continuous individual numbers 0 through 3 (four sets) for Cylinder 1

NOTE Number belts may be used in lieu of the above.

3. X-ray control number (use original control number assigned to each weld after fabrication)

B. Industrial X-ray film (Kodak type "M") 70 mm (212 pieces 14 inches in length)

C. Eighteen-inch collimators (two)

D. X-ray machines, 100 kv (two)



E. X-ray work platform (8EH-5119)

F. Lead vinyl shielding

NOTE: The vertical (splice) welds are inspected with the vehicle in a horizontal position located on a vehicle transporter.

Procedure for Inspection

A. Placement of identification markings

NOTE: All vertical welds will have view numbers placed on the inboard surface except for Cylinder 1 which has view numbers placed outboard. View numbers placed on the inboard surface will face outboard.

1. Place view numbers in an aft-to-forward direction. Number "0" is placed at the aft intersection of each cylinder and the subsequent numbers placed numerically in 10-inch increments.
2. Identify the X-ray views on the outboard surface with the use of magnets and stud finders for convenience of positioning the tubehead.

B. Placement of X-ray film and shielding

1. Place each 14-inch piece of X-ray film individually at the location to be exposed immediately prior to each exposure. The area to be exposed is shielded with lead vinyl backing.
2. Remove the previously exposed X-ray film and place an unexposed piece at the adjacent position along with the lead vinyl backup shielding. This procedure is continued for the entire length of the vertical splice.



C. Setup of X-ray equipment (Figure 1-34)

1. Position an 8EH-5119 workstand on the side of the vehicle adjacent to the circumferential weld joining the common bulkhead to Cylinder 1.
2. Mount two X-ray tubeheads to the holding fixtures on the workstand.
3. Remove the lead protective covers (plugs) and install the collimators.
4. Align the collimators with the weld centerline at View 0-1 and adjust to a position perpendicular to the welds.

D. Exposure procedure

1. Determine the material thickness from the thickness chart.
2. Select the proper machine settings from the technique curve
3. The X-ray machine is activated after adherence to all safety procedures.
4. Move the X-ray workstand to the next adjacent exposure position after making the exposure. Continue consecutive exposures for the entire length of the splice, processing the exposed X-ray film intermittently during the process.
5. Rotate the vehicle so the next splice weld is in position for inspection. Repeat Exposure Procedures 1 through 4 for the remaining three splices.
6. Deactivate the X-ray machines and remove the keys.
7. Install the collimator covers or remove the collimators and replace the lead plugs.



1.3.12 LH₂ TANK FUEL OUTLETS AND FILL AND DRAIN WELDS AFTER PNEUMATIC TESTING

Special Equipment and Materials Required

- A. Lead identification markings
 - 1. Templates with preplaced numbers
 - 2. X-ray control number (new number assigned)
- B. Industrial X-ray film (Kodak type "M") 70 mm
 - 1. Forty strips especially cut to template configuration for fuel outlets
 - 2. Twelve pieces especially cut to template configurations for fill and drain
- C. X-ray work platform, Tool No. 8EH-5119
- D. Lead vinyl shielding

NOTE This inspection is performed with the vehicle in a horizontal position located on a vehicle transporter

Procedure for Inspection

- A. Placement of identification markings - Position a template with preplaced view numbers on the outboard surface. View numbers are oriented as a clockface and should be so placed when facing the weld in flight position.

NOTE X-ray is only required in the accessible areas of the fuel outlet welds (i.e., 8 o'clock to 4 o'clock).

- B. Placement of X-ray film and shielding
 - 1. Place each X-ray film individually in the area to be exposed immediately prior to each exposure
 - 2. Use lead vinyl in the exposure area for backup shielding.



C. Setup of X-ray equipment

1. Position the 8EH-5119 workstand adjacent to a fuel outlet.
2. Mount the X-ray tubehead to the holding fixture on the workstand.
3. Remove the lead protective cover and install the collimator.
4. Align the collimator with the weld centerline and adjust to a position perpendicular to the weld.

D. Exposure procedures

1. Determine the material thickness from the material thickness chart.
2. Select the proper machine settings from the technique curve
3. The X-ray machine is activated after adherence to all safety procedures.
4. Expose each required X-ray view and process the X-ray film.
5. Rotate the stage to the next fuel outlet and repeat the procedure
6. Setup and exposure is identical for the fill and drain weld, except that all views are accessible.
7. Deactivate the X-ray machine and remove the key
8. Install the collimator cover or remove the collimator and replace the lead plug.

1.4 RADIOGRAPHIC TECHNIQUES FOR DETERMINING WELD FLAW DEPTH LOCATIONS

This section defines the radiographic techniques used to determine flaw depth locations in Saturn S-II weldments at the North American Rockwell Space Division.

There are many variations of radiographic methods and techniques that can be used to determine the flaw depth location in weldments. The triangulation technique described in this section has been refined to a simple and accurate form to achieve optimum results. However, it is imperative that the radiographer completely understands the use of this technique to assure that flaw depths are located accurately.

TECHNIQUE DESCRIPTION

To ascertain flaw depths using this triangulation technique, a single-lead tape marker is placed adjacent to the flaw location on the tube-side of the weldment. Only one X-ray film is used, but it is exposed from two different tubehead positions. The first exposure (at one-half of normal exposure time) is made at a right angle (normal) to the weld. The second exposure is made after the tubehead is displaced (at the same focal distance) and tilted at an angle of approximately 30 degrees to the normal so that the beam center penetrates the weld in the location of the flaw (Figure 1-35). The defect location (height of the flaw above the film plane) is determined through the use of an X-ray triangulation chart (Figure 1-36). The chart is based on the use of the tangent function in similar right angles (i. e., $\tan C = c/b$ where C is the tilt angle of the tubehead, c is the shift distance of the flaw on the radiograph, and b is the distance from the film to the flaw).

The triangulation chart (Figure 1-36) is used in the following step-by-step sequence

1. Measure the displacement of the tube-side marker as shown on the radiograph.
2. Locate this dimension on the right-hand scale of the triangulation chart (image displacement, c).
3. Intersect the horizontal line from this point with the vertical line taken from a point on the bottom scale (defect location from film plane) which represents the total thickness of the material containing the flaw.

4. Intersect these two lines with a diagonal line (exposure angle, C) to indicate the true angle of the second exposure.
5. Measure the displacement of the flaw as shown on the radiograph.
6. Locate this dimension on the right-hand scale (image displacement, c) of the triangulation chart.
7. Intersect a horizontal line from this point with the diagonal angle line determined in Step 4.
8. Read the bottom scale at this intersection for the dimension indicating the defect location from film plane.

NOTE: To obtain accurate depth measurements using this system, it is important to place the film in direct contact with the part. If not, the distance between the film and part is added to the material thickness used in Step 3.

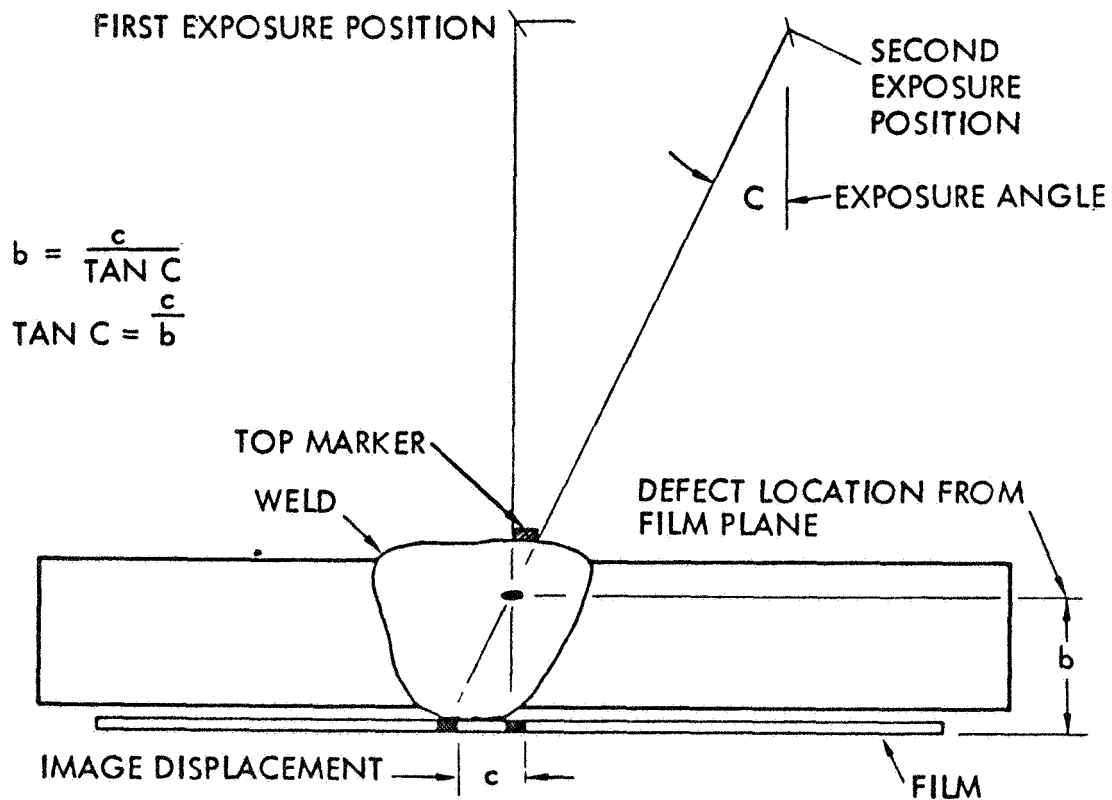


Figure 1-35. X-Ray Exposure Position

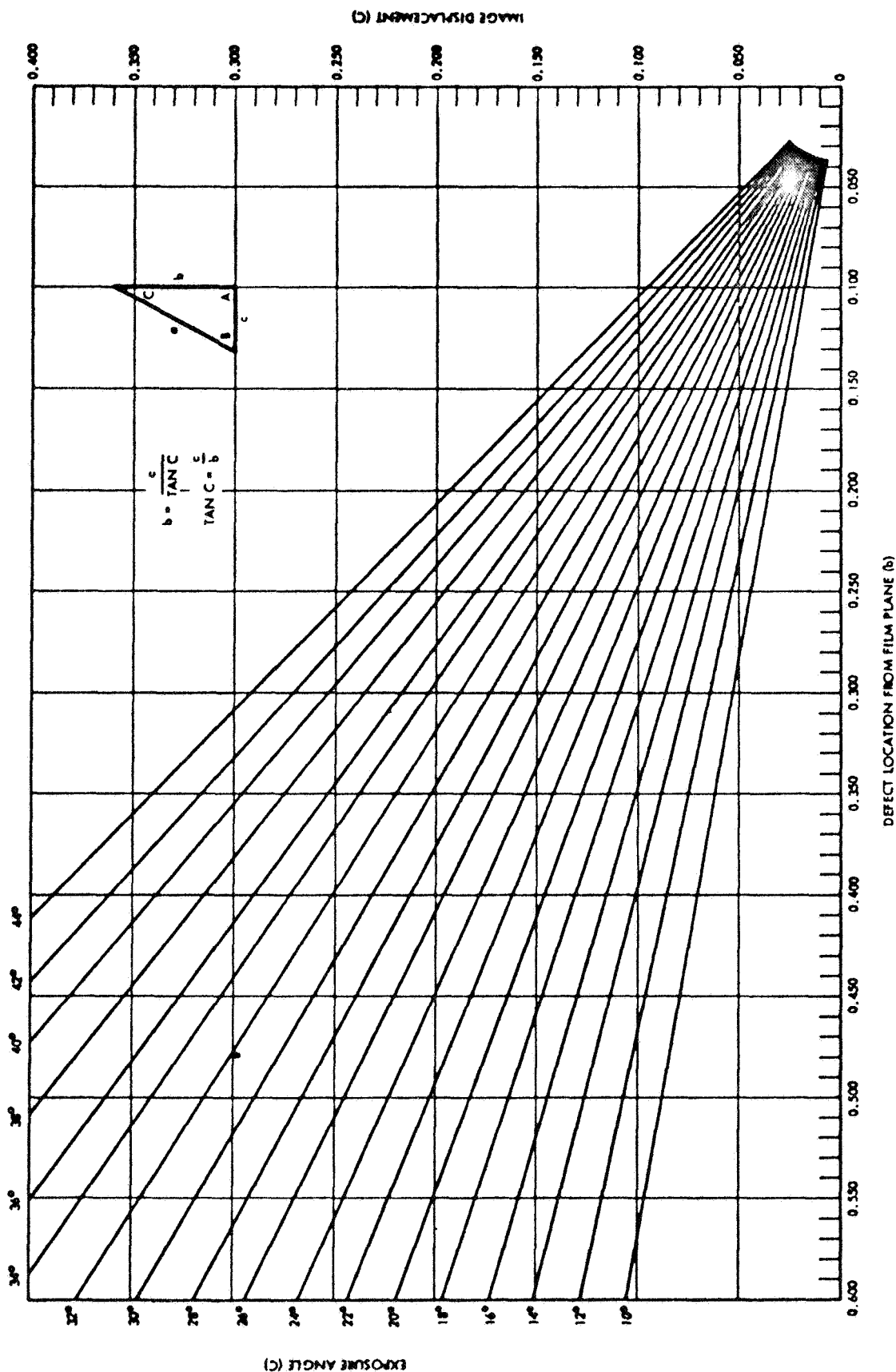


Figure 1-36. X-Ray Triangulation Chart

1.5 RADIOGRAPHIC INSPECTION OF DEBRIS BARRIER

The area of the forward skirt between Stations X_B824 and X_B848 is X-ray inspected by directing the radiation completely through the stage (see Figure 1-37). The radiographs, which reveal the internal area of the cavity formed by the forward LH₂ bulkhead and the forward skirt assembly, are examined for any foreign objects in this cavity area (see Figure 1-38).

This is the only X-ray task at the Seal Beach facility that is not completely shielded to allow personnel in close proximity to the X-ray source during actual exposures. Because of the high radiation intensity (260 kv) and the impracticability of completely shielding the scatter radiation produced by penetrating through the entire stage assembly, special precautions are required during this X-ray task. To assure strict adherence to the radiation safety procedures for this task, a certified radiographic leadman or supervisor should be present during all exposures.

EQUIPMENT AND MATERIALS REQUIRED

1. Lead identification markers
 - a. Alternate numbers 1 through 143 (two sets)
 - b. X_B locating markers X_B824, X_B836, and X_B848 (12 of each)
 - c. Position markers I, II, III, and IV (two sets)
 - d. X-ray control number (new)
2. Industrial X-ray film (Kodak type "M") 12-inch width 'Day Pak', 24 feet in length, 12 pieces.
3. X-ray tubehead holding fixture, Tool No. 8E-0863-H1 (Figure 1-39) (collimator is constructed as part of the holding fixture)
4. Sperry 275-kv X-ray machine (Figure 1-40)



Figure 1-37. Positioning Tubehead and Primary Radiation Shields for
X-Ray of Debris Barrier

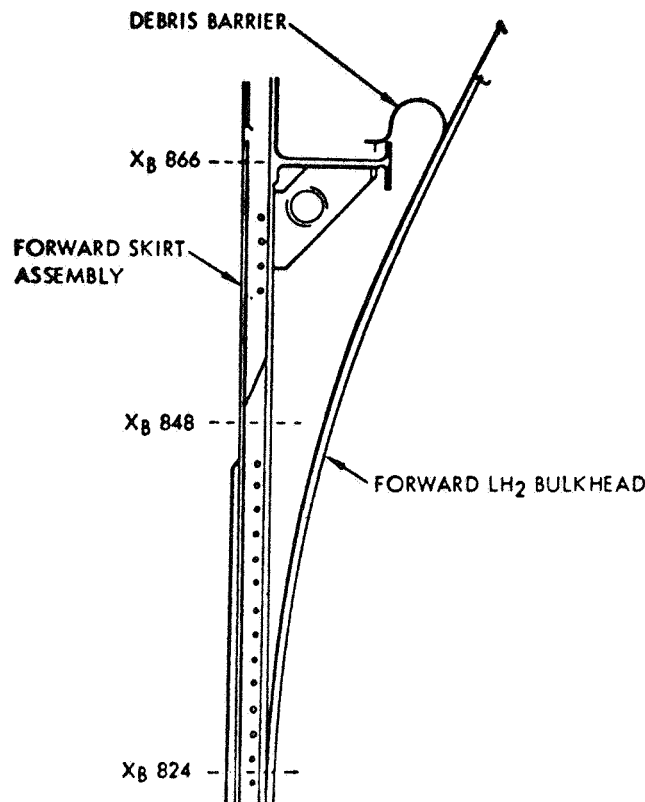


Figure 1-38. Debris Barrier Cavity

5. Four special lead backup shields, Tool No. 8EH-0856 (Figure 1-41)
6. Man shield - no tool number

PROCEDURE FOR INSPECTION

Placement of identification markings

1. Forward skirt stringer identification markers are placed on the outboard surface of the forward skirt.
2. Each odd-numbered stringer is identified. Stringer identification markers are placed at approximately XB 826 and XB 838 on each odd-numbered stringer.

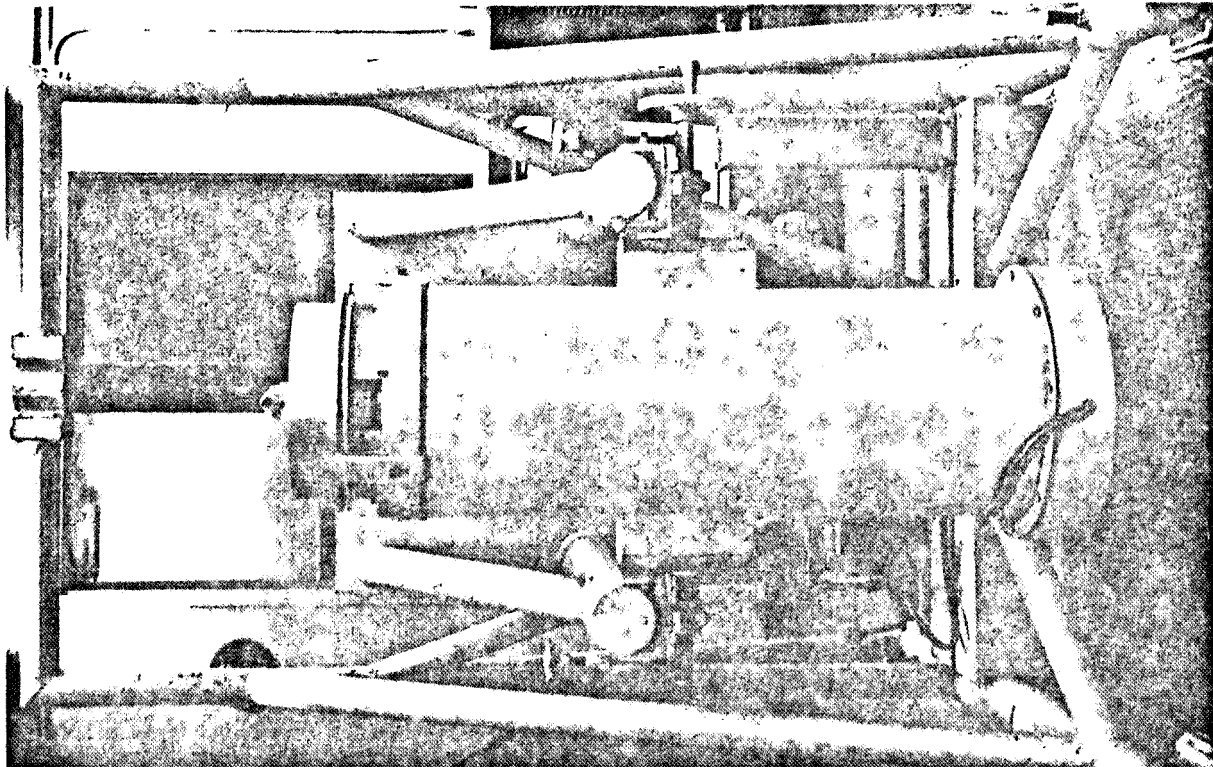
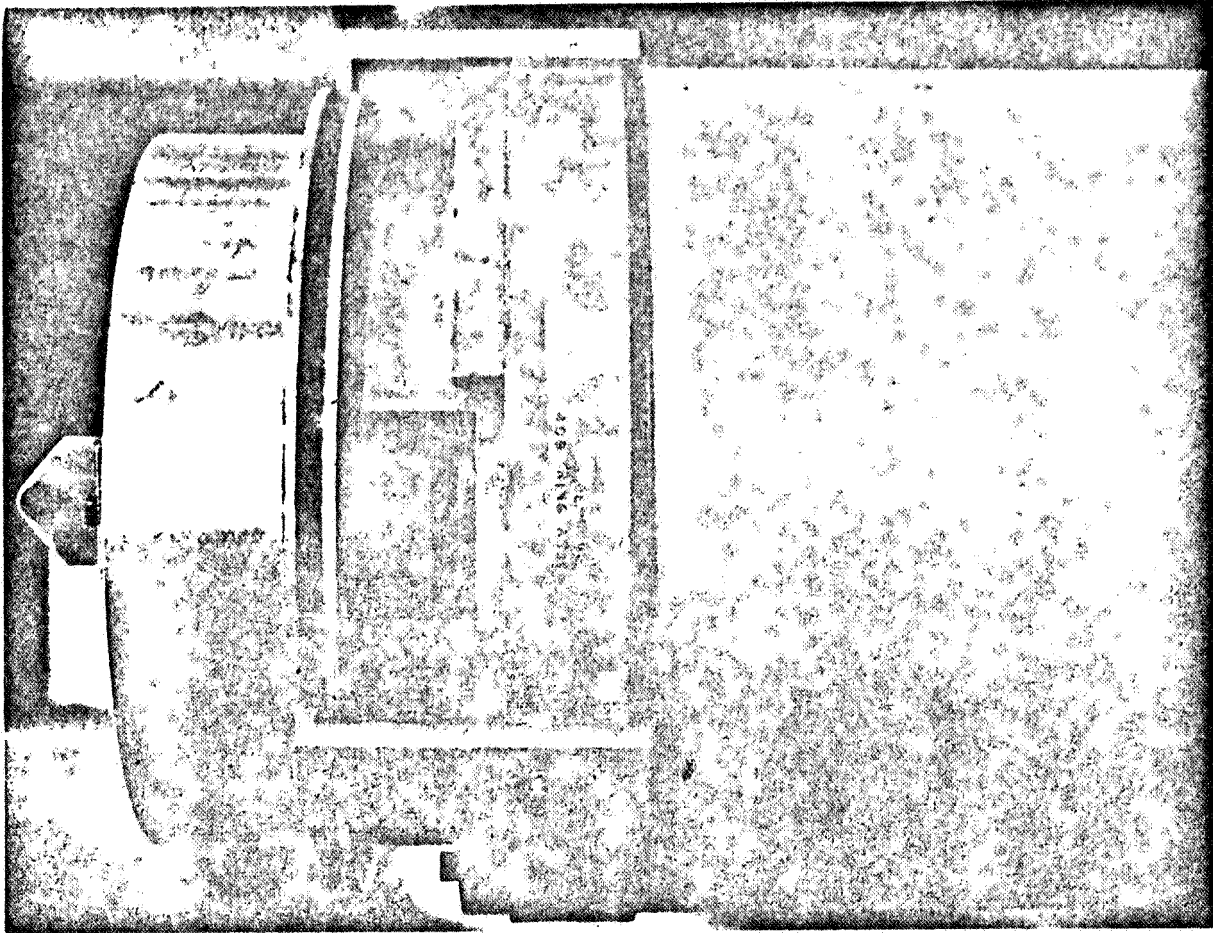


Figure 1-39. X-Ray Tubehead Holding Fixture and Collimator



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North American Rockwell

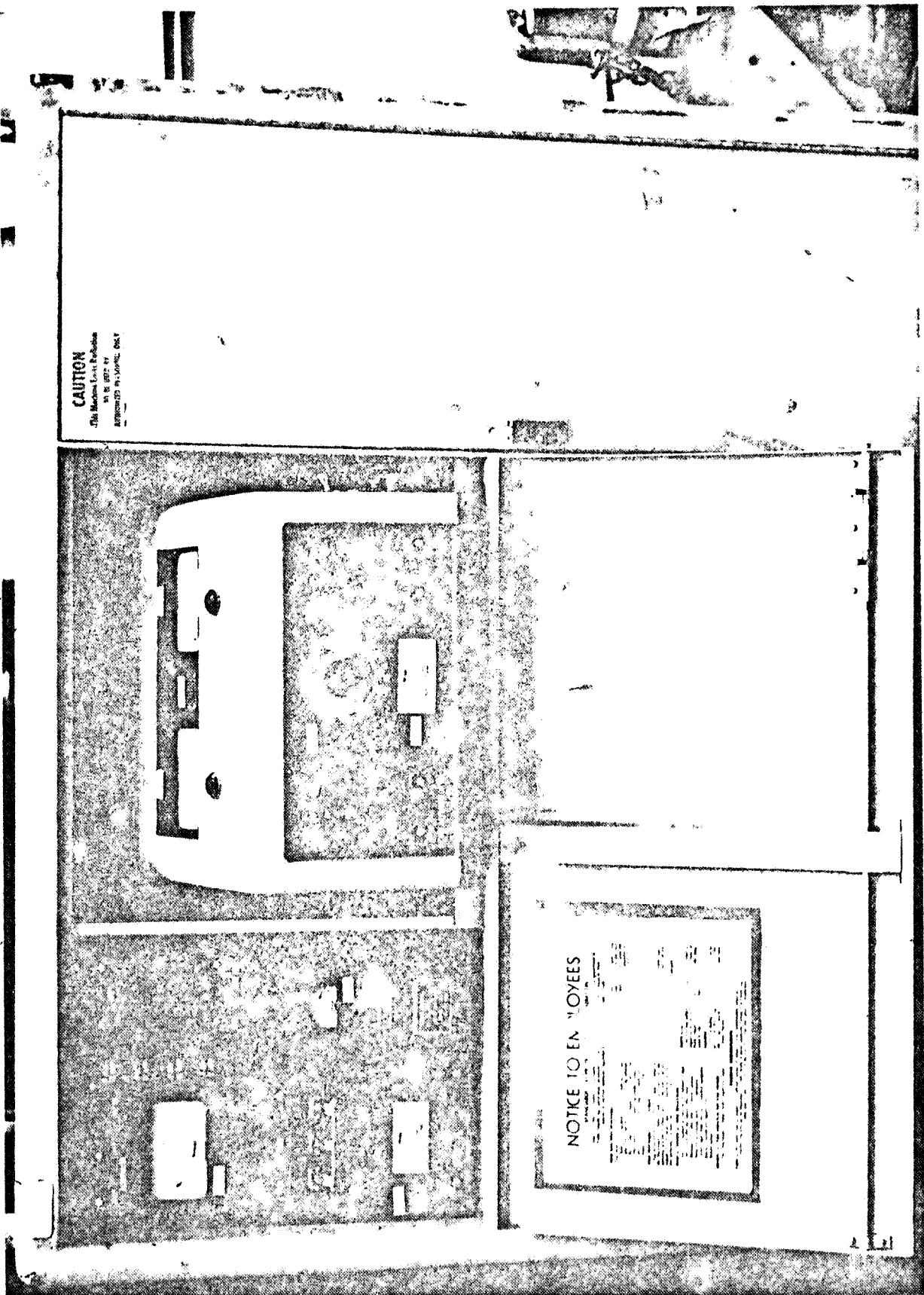


Figure 1-40. Sperry 275-Kv X-Ray Unit

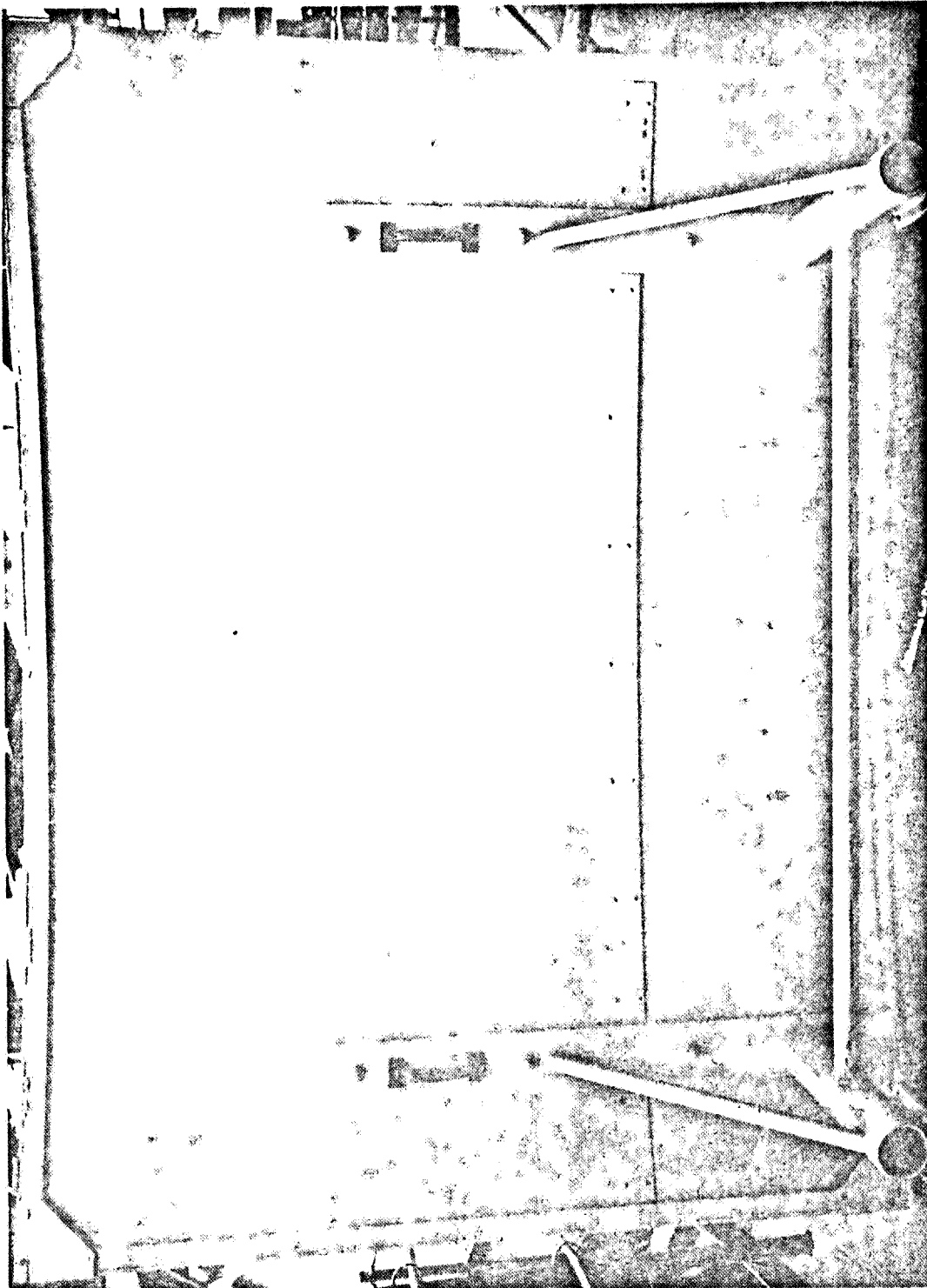


Figure 1-41. Lead Backup Shielding (Primary Radiation)

3. Position markers I, II, III, and IV are also appropriately placed at X_B826 and X_B838.

NOTE: Forward skirt stringers do not correlate with LH₂ tank and aft skirt stringers.

Placement of X-ray Film

1. One strip of X-ray film is placed on the forward skirt at X_B824 to X_B836. This film should cover 24 stringers with some excess at each end for overlap. A second strip of X-ray film is placed at X_B836 to X_B848 covering the same stringers as the first film.

NOTE: Six exposures are required to completely circumvent the forward skirt.

2. Placement of film for the second exposure is located as defined in Step 1 except the center of the second exposure is located 24 stringers from the center of the first exposure.
3. Placement of film for the subsequent four exposures is as defined in Steps 1 and 2 above.

Setup of X-ray Equipment (See Figures 1-38 and 1-42)

1. The X-ray machine and tubehead holding fixture are placed directly opposite the area to be exposed (72 stringers from the center of the 24-stringer X-ray view).
2. The X-ray tubehead is mounted to the holding fixture (Tool No. 8E-0863-H1).
3. The tubehead is aligned perpendicular to the skirt at X_B836. The tubehead is placed 72 stringers from the center of the inspection area.
4. The X-ray tube is positioned as near to the skirt as practicable.

Exposure Procedure

1. The X-ray machine is set for the following technique:

260 kv
10 ma
10 minutes

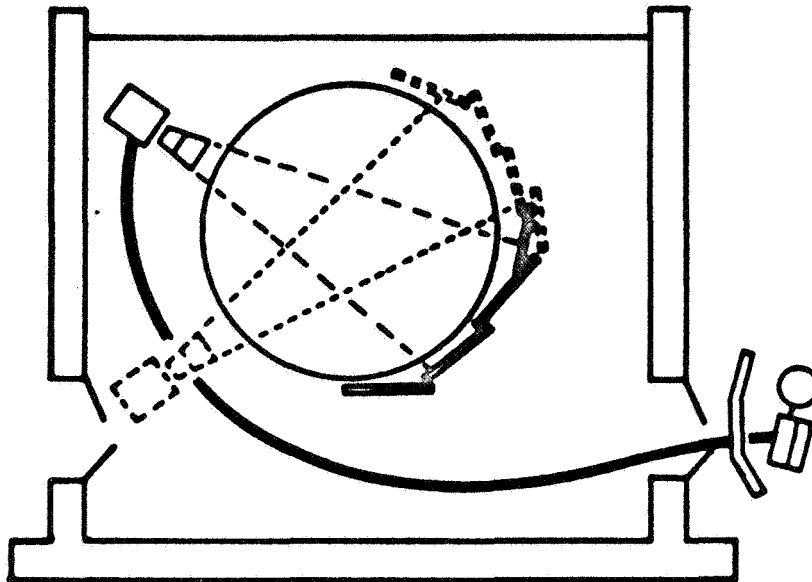


Figure 1-42. Typical Setup for
Debris Barrier X-Ray

2. The X-ray machine is activated for the first exposure after adherence to all safety procedures.
3. The exposed X-ray film is removed and the unexposed film placed in the next adjacent inspection area.
4. The X-ray tubehead and holding fixture are rotated 24 stringers so that they are again directly opposite the inspection area.
5. The procedures under Placement of X-ray film, setup of X-ray equipment and Exposure Procedure are repeated for the remaining five exposures.
6. The X-ray machine is deactivated and the key removed.
7. The exposed X-ray film is processed in the automatic film processor.



1.6 INTERPRETATION OF RADIOGRAPHS

The interpretation of radiographs of Saturn S-II welds is an extremely critical inspection process. Experience reveals that very tight cracks can exist in the welds which are visible on the radiographs but which can be overlooked. To prevent any significant flaw from escaping detection, a redundant system of radiographic interpretation has been established. Additionally, each area that is most susceptible to flaws (such as rework areas) is identified and subjected to extracritical radiographic examination. This system allows an expeditious initial film interpretation with a backup system to assure that no defect escapes detection.

PROCEDURE

The radiographic inspector interprets and evaluates the radiographs listing all anomalies observed on the radiographic inspection report. He grades the severity of all anomalies in accordance with the applicable drawing or specification.

A second radiographic inspector interprets and evaluates the same radiographs listing all anomalies on a work sheet. He also grades all anomalies in accordance with specification and drawing requirements.

The radiographic inspection leadman or supervisor reviews and correlates all significant anomalies noted by the two radiographic inspectors assuring that they have been properly recorded on the radiographic inspection report. He also reviews all critical weld areas. The critical areas are designated as all weld intersections, weld start and stop areas, weld machine malfunction or erratic operation areas, and weld-reworked areas. The leadman or supervisor notes the specific areas he reviewed on the radiographic inspection report and signs the "Approved By" block to reflect his concurrence with the finalized interpretation.



The responsible radiographer then transfers all rejectable discontinuities to a standard discrepancy (squawk) form which is integrated into the Fabrication and Inspection Records (FAIR) or Test and Inspection Records (TAIR) system in accordance with the standard Quality Assurance Manual procedure.

The leadman or supervisor then either disposes the discrepancies entered on the squawk sheet, if authorized by the process specification, or refers the out-of-tolerance condition to the Material Review Board for its evaluation and disposition.

1.7 TECHNICAL REVIEW AND AUDITS OF RADIOGRAPHIC OPERATIONS

This section defines the procedures established by Quality Engineering to assure that the highest quality and reliability standards for radiographic inspection processes performed on Saturn S-II hardware are consistently maintained.

The section outlines the criteria established for Quality Engineering specialists to conduct a 100-percent technical review of all radiographic film related to each weldment. This review includes evaluations of film following completion of individual welding operations and of radiographs exposed after completion of subassembly and/or full-stage pressure testing cycles. The reviews are time-phased to preclude any schedule impact in the event that a critical weld defect is discovered. Additionally, this section defines the provisions for accomplishing monthly, unscheduled internal audits of the processing sequences, methods, and techniques utilized by Quality Assurance personnel during S-II stage weld inspection operations. The audit provides the necessary controls for consistently maintaining an effective and reliable radiographic inspection system.

TECHNICAL REVIEW OF RADIOGRAPHIC FILM OF WELDMENTS

The technical review of radiographic film associated with each specific, individual weld and/or subassembly will be scheduled as described in the following paragraphs.

Meridian Welds in Aft Facing Sheet, Forward Facing Sheet, Forward LH₂, and Aft LO₂ Bulkheads

This review is performed upon completion of all meridian welds contained in a bulkhead assembly (including all documented weld repairs). The reviews are conducted prior to welding the dollar ring into each assembly and before individual bulkheads are removed from the welding tool.

Dollar Welds for Aft LO₂, Forward LH₂, Aft Facing Sheet, and Forward Facing Sheet Bulkheads

The reviews are initiated following completion of the welds and final acceptance of film of each welding operation (including any required weld repairs). The reviews are completed before individual bulkheads are removed from the welding fixture.



Aft LO₂, Aft Facing Sheet, and Forward LH₂ Bulkhead Assemblies

The reviews of radiographs of welds that are X-rayed following the hydrostatic testing cycle for each unit are made before initiating any subsequently scheduled welding or bonding operation on the individual assemblies.

Vertical Weld Splices for LH₂ Tank

All film related to vertical splice welds are reviewed following final acceptance of individual cylinder assemblies. The reviews are completed before each cylinder assembly is removed from the weld fixture.

LH₂ Tank Circumferential Weldments

The films for individual welds joining cylinder assemblies are reviewed following final acceptance (including all required weld repairs). The radiographs of each circumferential weld joining Cylinder 2 to Cylinder 3 (stage closeout weld) are reviewed prior to performing the pneumatic testing sequence for a completed tank.

LH₂ Tank and LO₂ Tank (Completed Stage)

The radiographs of all welds requiring inspection (including any repairs performed) are reviewed following pneumatic testing cycles and subsequent final acceptance. These reviews are concluded in as timely a manner as possible following post-pneumatic test inspection operations to preclude schedule impact.

REPORTS - FILM REVIEWS

Upon completion of the film reviews, Quality Engineering forwards the evaluation results in an internal letter to the appropriate NR SD QA supervisory personnel. Upon completion of its efforts associated with LH₂ and LO₂ tank welds, Quality Engineering prepares a summary for the applicable stage that outlines (1) the individual reviews that have been performed, (2) at what point in stage fabrication/assembly the reviews were conducted, and (3) the results of the final review.

If at any time during the outlined radiographic film reviews a critical defect is discovered (i.e., one that may require repair or could impact the schedule), QA supervision is notified immediately to initiate the necessary action.



TECHNICAL AUDITS OF RADIOGRAPHIC PROCESSING OPERATIONS

Two primary areas of control provide the basis for establishing a technical audit system and performing the frequent evaluation of personnel capabilities and radiographic methods. The objective for implementing such a system is to assure that high-quality radiographic film is consistently obtained and effective personnel and processing methods are always employed on parts and assemblies. These primary areas of control that pertain to maintaining efficient radiographic processing operations are described in the following paragraphs.

Automated Film Processing

Because the quality of any final radiograph is dependent upon the developing process, it is mandatory that the automatic film processors always be rigidly controlled to achieve maximum efficiency and consistency. The method selected for the control point is that which establishes the processing of standard exposure, step-wedge radiographs at regular intervals. By recording the densities exhibited in these films, the date and time that processing is accomplished, and the developer solution temperature, any anomalies and/or variables present in the processing system can be detected and corrected immediately.

Standard X-Ray Machine Techniques

Approved documented techniques or standard procedures are required for each X-ray machine and for each material thickness on which the individual machines will be utilized. These techniques must be capable of consistently producing high-quality radiographic film. Therefore, if a quality deficiency occurs once such techniques are established, no deviations will be allowed, unless the cause of the inadequacy has been determined and corrected.

AUDIT PROCEDURE FOR RADIOGRAPHIC OPERATIONS

The internal NR SD audit of S-II radiographic operations are scheduled at irregular intervals on a monthly basis without prior notification to other than the supervisor of the immediate functional area. All audits of radiographic processing techniques employed include a review of the operational categories described in the following paragraphs.

Radiographs

A technical review of each film for each Saturn S-II tank weldment is required as previously described. This evaluation includes determinations for (1) the quality of the radiographic film, (2) accuracy in identifying apparent defects in the radiographs (i. e., film or defect interpretation),



and (3) completeness of the controlling documentation and the results associated with the film.

Film Reading Area

Emphasis in this area is placed on an examination of the film processing and viewing areas for their conformance to requirements, such as maintenance of proper lighting, acceptability and condition of equipment, availability of applicable documents, etc.

Machine Techniques

The review of procedures developed and approved for the operation of each X-ray machine includes an evaluation of radiographic film obtained specifically to verify the acceptability of the procedural techniques for each X-ray machine.

Reports

Written reports of completed technical audits are submitted to inspection management and the area supervisor upon completion of each monthly audit. These reports include (1) a description of deficiencies encountered and (2) recommended corrective actions needed to improve the deficient functional areas in the processing system.



2.0 FLUORESCENT-PENETRANT INSPECTION PROCESSES

2.1 STANDARD MATERIALS AND EQUIPMENT USED

The following information is presented to enable inspectors to become more familiar with the materials and equipment items used in performing fluorescent-penetrant inspection operations on parts and assemblies for S-II stages.

Personnel who perform (or assist in performing) fluorescent-penetrant inspection operations should be cognizant of the information contained herein. This section is structured generally to describe the terminology, types of materials, and equipment items utilized for fluorescent-penetrant inspections and to provide information about the requirements for qualification tests and control of these items.

PENETRANT MATERIALS

The penetrant materials described in the following paragraphs are not the only materials permitted within the applicable specifications, however, they are the materials used for S-II production.

Paste-Etch - Turco 5361

Turco Co. of Los Angeles produces this paste-etch which is basically sodium hydroxide thickened with a neutral or inert filler, such as Cab-O-Sil. Its alkaline nature (pH13 to pH14) causes it to readily react with aluminum alloys. Hence, this paste-etch is applied to smeared metal areas caused by grinding, machining, or polishing to remove from 0.0004 to 0.0006 inch of metal so that hidden discontinuities may be exposed for penetrant inspection.

Because sodium hydroxide is caustic, care must be exercised to avoid contact with the skin. If such occurs, water flushing of the affected areas should be accomplished immediately.

LO₂ Compatible Penetrant P-545

The P-545 system is supplied by Shannon Luminous Materials Co., Los Angeles. It is considered LO₂-nonreactive or LO₂-compatible since the material does not react in the standard LO₂-impact tests defined in NASA Specification MSFC-106B or AF Bulletin 527. This penetrant material



consists of a reactive fluorescent dye dissolved in a nonreactive, liquid fluorocarbon carrier and diluted with a nonreactive volatile liquid extender such as methylene chloride which reduces the surface tension of the solution.

The P-545 penetrant material exhibits a brilliant blue fluorescence when excited by long-wave ultraviolet light (3650 angstrom units). This color characteristic is desirable for two reasons. First, the use of a single-component (blue) fluorescent-dye system minimizes the possibility of LO₂-reactivity because fluorescent green color-formers normally have poor solubility in fluorocarbon liquids and might have a tendency to crystallize out of solution. Second blue color-formers fluoresce properly when maintained in solution with a liquid fluorocarbon.

K-410A Remover (for P-545 Penetrant System)

K-410A is a standard chlorinated solvent (perchloroethylene) which is used to remove surplus penetrant from surfaces, leaving the penetrant entrapped in any surface discontinuities. (Wipe cloth dampened with this material is used to remove the excess penetrant from surfaces before developer is applied.

Penetrant - P-149

Shannon Luminous Materials Co. of Los Angeles manufactures this product which is a high-sensitivity oil-phase, fluorescent penetrant. Like all oil-phase fluorescent penetrants, it contains an oil base to which a brilliant fluorescent dye has been added. When this product is applied to the surface of a part, it penetrates into any flaws open to the surface. After removal of the surplus penetrant from the surfaces, the residual material remains entrapped in the flaws. Capillary action causes the penetrant to bleed out from the entrapped area. The entrapped dye responds by fluorescence when excited by an ultraviolet light source (3650 angstrom units). The intensity of the resulting fluorescent response is a function of the concentration of dye in solution, the film thickness of the entrapped penetrant, and the intensity of the radiation source (black-light).

Emulsifier - E-153 (For P-149 Penetrant System)

Manufactured by Shannon Luminous Materials Co., this emulsifier is essentially a nonionic detergent material which acts as an oil/water coupling agent. When the emulsifier is applied to a surface coated with penetrant, it blends with the penetrant rendering it water soluble. When the emulsifier is applied to surfaces containing entrapped penetrant it not only emulsifies the penetrant on the surface, but also enters flaws, forming a water-soluble



zone within the entrapment area. Prolonged emulsifier contact time with penetrant will result in a loss of fluorescent sensitivity because of the dilution of penetrant within the entrapment zone.

Developer - D495A (For P-149 and P-545 Penetrant Systems)

This material is a product of the Shannon Luminous Materials Co., Los Angeles. The developer absorbs and fixes penetrant entrapped in small flaws and builds up the effective penetrant film thicknesses, thereby augmenting the color contrast or fluorescent brightness. The developer also provides a white background which enhances color and brightness.

QUALIFICATION AND ACCEPTANCE TESTS FOR PENETRANT MATERIALS

Qualification tests for penetrant system materials are performed by a Government qualifying agency. Acceptance testing of subsequently produced penetrant materials is performed by the manufacturer only. All materials must be tested to and meet the requirements of MIL-I-25135C and be listed in NR SD Qualified Products List (QPL) 25135. Specifically, the requirements and acceptance tests performed by the manufacturer for each batch of materials are described in the following paragraphs.

Fluorescent Penetrant

1. Fluorescent brightness - The material shall be comparable to either the brightness exhibited by a sample retained from the original qualification test material or to a standard dye solution using the meniscus spot-test method. A minimum of 40 foot-lamberts is required.
2. Viscosity - The material shall conform within ± 15 percent when compared to the design center established for qualification test material and measured on the Saybolt scale.
3. Flash point - The material shall not exhibit a flash point below 125 F (minimum).
4. Fluorescent stability - The material shall continue to exhibit a brightness of not less than 85 percent of the reference sample when exposed to black light for 1 hour.
5. Sensitivity - The material is tested for sensitivity by comparison with a reference sample using the meniscus test method and the ceramic block test method.



6. Penetrant removability - Penetrant material shall be readily removable after treatment with an applicable emulsifier or remover.

Emulsifiers

1. Viscosity - The viscosity of the emulsifier shall be less than 100 centistokes (maximum) when measured at 100 F.
2. Flash point - The emulsifier shall not exhibit a flash point below 125 F (minimum).

Developers

1. Fluorescence - The developer shall exhibit no fluorescence when tested under ultraviolet light.
2. Flash point - The developer shall not exhibit a flash point below 125 F (minimum).

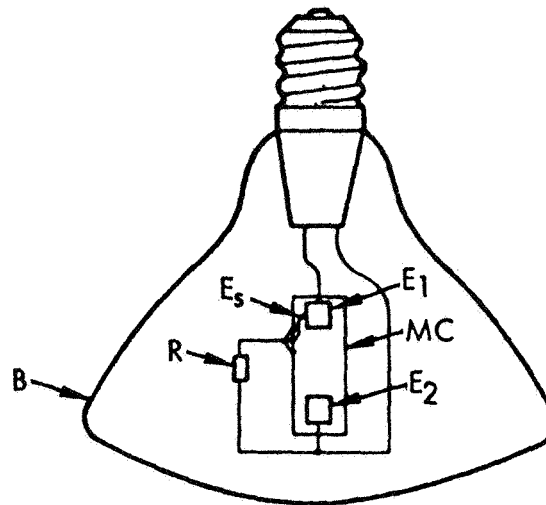
All materials must be capable of being stored under warehouse conditions for a period of not less than 1 year without any change in figure of merit.

ACCEPTANCE AND VALIDATION TESTS FOR LO₂ COMPATIBLE PENETRANT MATERIALS (NR SD)

Acceptance tests to be performed by NR SD on each batch of penetrant material shall consist of a liquid oxygen (LO₂) compatibility (sensitivity) evaluation according to the NR SD Material Specification MB0210-006. Validation is required for these penetrant materials which will be employed on parts and assemblies that will be used in LO₂ systems, i.e., "parts and assemblies which, because of their ultimate usage, will come into contact with liquid oxygen." The validation tests shall consist of an LO₂ compatibility (sensitivity) check of each batch in use every 30 days in accordance with the requirements defined in NR SD Process Specification MA0115-005.

ULTRAVIOLET LAMPS (BLACK LIGHT)

A mercury-vapor lamp is used as the source of ultraviolet energy for fluorescent-penetrant inspection operations. Mercury-vapor lamps are gaseous-discharge devices in which an electrical arc takes place in a controlled atmosphere and emits light. The construction and function of a typical mercury-vapor bulb are depicted in Figure 2-1.



NOTES:

- MC - Quartz or hard-glass cartridge in which mercury vapor is confined
- E₁ and E₂ - Main electrodes that carry current to the arc stream which is activated along the length of the cartridge
- E_s - Auxiliary starting electrode
- R - Current limiting resistor
- B - Outer protective bulb in which the assembly is sealed

Figure 2-1. Construction and Function of Typical Mercury-Vapor Ultraviolet Lamp (Black Light)

Power for the lamp is obtained from a portable, self-contained, constant-voltage transformer unit attached to the light. To facilitate starting, a small amount of neon gas is incorporated into the cartridge or glass shell, and a starting electrode is sealed through one end of the tube near one of the main electrodes. Mercury is also contained in the interior of the tube in droplet form. When the lamp is first energized, an arc takes place from the starting electrode through the neon gas. This arc carries a relatively small current which is limited by the protective resistor (R) but is sufficient in strength to vaporize or ionize the mercury droplets and eventually cause a second arc to strike between the main electrodes. This heating and ionization process requires about 5 minutes from the time voltage is first applied to the lamp.

NOTE Extreme care must be taken not to break the lamp thus releasing the mercury contained in the cartridge. Mercury metal is a poisonous material which readily amalgamates (reacts) with aluminum. In addition, mercury vapor is equally toxic if inhaled. Therefore, if breakage of a lamp should occur (particularly in enclosed areas such as interiors of the S-II stage propellant tanks), Inspection supervision must be notified immediately to implement corrective action.

Because only the black-light portion of the radiation spectrum is desired for inspection activities, the remainder of the radiation spectrum is removed by use of a red-purple glass filter. The characteristic wave length of the filtered light is 3650 angstrom units.

The intensity of the light output of a black-light lamp decreases gradually with use and age. Discoloration of either the cartridge or the outer container or a dirty filter can decrease light output. Failure of the light will occur when the active mercury material has been expended from the electrodes.

CALIBRATION REQUIREMENTS FOR ULTRAVIOLET LAMPS

Functional calibration of black lights is performed on a weekly basis. Using a Weston light meter (Model 703-60), the intensity of the black light must measure 125 foot-candles at 15 inches from the face of the lamp. In addition, formal calibration of instruments is required every 6 months in accordance with NR SD Calibration Procedure 1030-9.

2.2 INSPECTION PROCEDURES

This section describes the procedures followed by Quality Assurance personnel during inspection sequences on Saturn S-II metal structures that involve the use of fluorescent penetrant for detection of surface discontinuities.

The information contained herein is intended to supplement the general procedures defined in NR SD Quality Control Specification MQ0501-004, "Inspection, Penetrant Method," which is the document governing fluorescent-penetrant inspection requirements at NR SD.

The techniques and methods utilized for surface preparation when performing fluorescent-penetrant inspection operations on aluminum alloys are also described in this section.

The procedures are structured to provide a means for achieving optimum conditions for the detection of surface discontinuities in parts, functional components, and structural assemblies.

2.2.1 CHEMICAL-ETCH CLEANING OF ALUMINUM ALLOYS PRIOR TO FLUORESCENT-PENETRANT INSPECTIONS

The following materials are required

1. Etchant for aluminum Turco 5361 caustic paste-etch
2. Deoxidizer for aluminum Diversey 514
3. Rinses deionized water and cheesecloth

All aluminum alloys are susceptible to metal flow or smearing as a result of performing such mechanical abrading operations as grinding, machining, or polishing. This movement of metal tends to mask or cover surface discontinuities and impedes detection of these discontinuities during any subsequent fluorescent-penetrant inspection evaluation. To obtain valid results, it is necessary to remove this smeared aluminum film with a caustic chemical etchant before penetrant inspections. When abrading operations are completed, the following chemical-removal procedure for metal is employed on aluminum parts in accordance with Process



**Specification MA0110-011, "Cleaning of Aluminum and Aluminum Alloys,"
before applying fluorescent-penetrant material to these surfaces'**

NOTE: The improper handling of caustic chemical solution for metal removal when preparing aluminum surfaces for penetrant inspection can cause considerable damage to the base material from corrosion. If these caustic etchants are not neutralized properly, corrosion will occur as a result of chemical attack and subsequent exposure to environmental weathering during service. Strict adherence to these procedures is mandatory to preclude inadvertent damage to parts and assemblies as a result of employing chemical etchants in conjunction with fluorescent-penetrant inspections.

1. Mask applicable areas with plastic sheeting (or equivalent) and lead-backed masking tape before initiating etching operations to prevent inadvertent damage to adjacent metal surfaces from accidental spillage of chemicals (see Figure 2-2).
2. Solvent-wipe the surface to be etched using clean cheesecloth dampened with trichloroethylene conforming to the requirements of NR SD Material Specification MB0210-003, 'Trichloroethylene, Reclaimable, Liquid Oxygen Compatible.'
3. Brush a uniform coating of Turco 5361 paste-etch onto the surface while exercising extreme care not to spill or drip this highly caustic material onto adjacent surfaces or other parts (see Figure 2-3).
4. Allow the Turco 5361 to etch the applicable surface for 15 to 25 minutes. After the first application of etchant, agitate the paste with swabs or spatulas, add fresh paste-etch at 3- to 5-minute intervals during the 15- to 25-minute dwell time.
5. Remove surplus Turco 5361 paste-etch by wiping the excess or residual material with clean cheesecloth (see Figure 2-4).

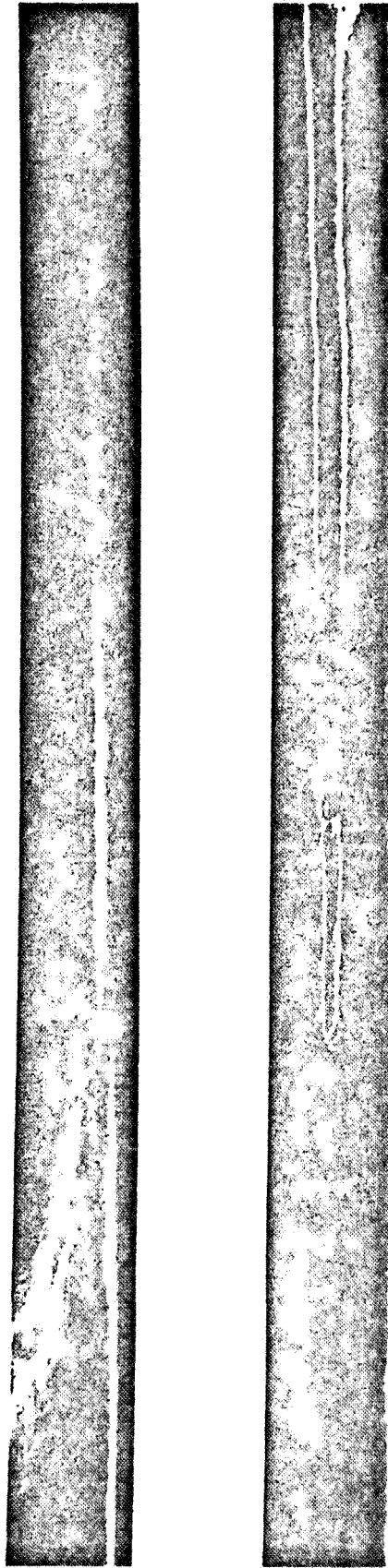


Figure 2-2. Plastic Used to Mask Off Weld for Chemical Etching

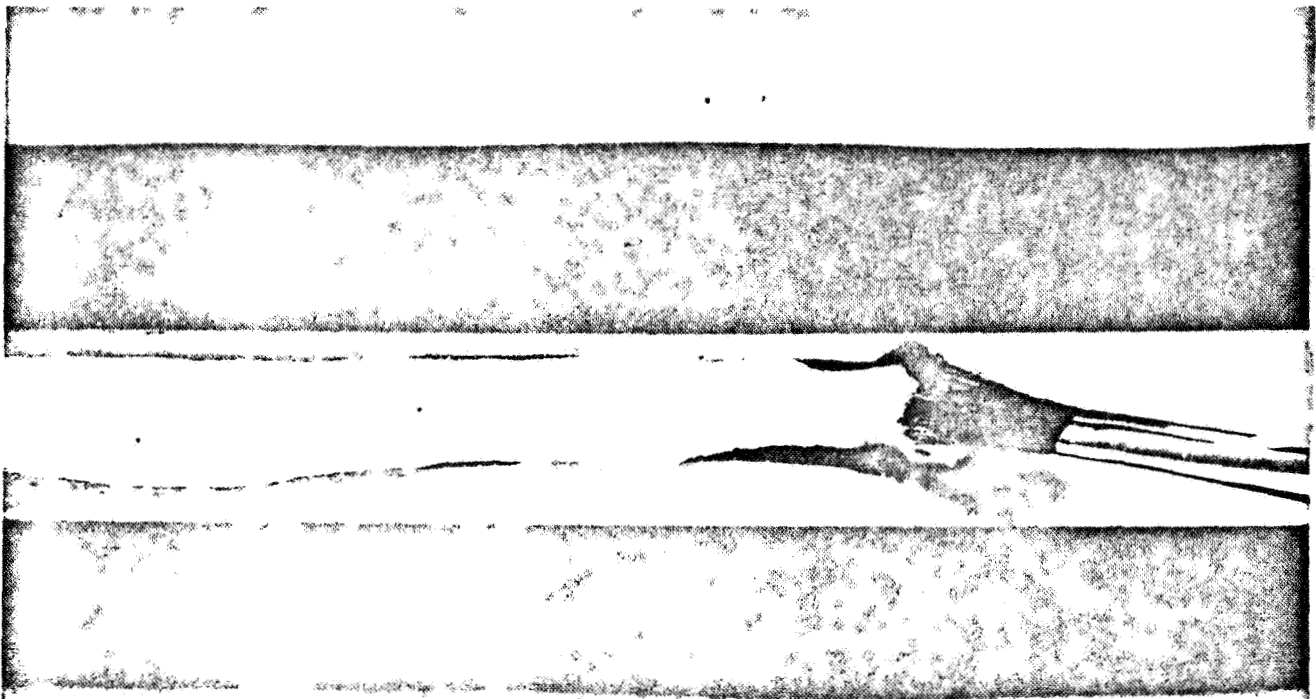


Figure 2-3. Application of Turco 5361 Paste-Etch

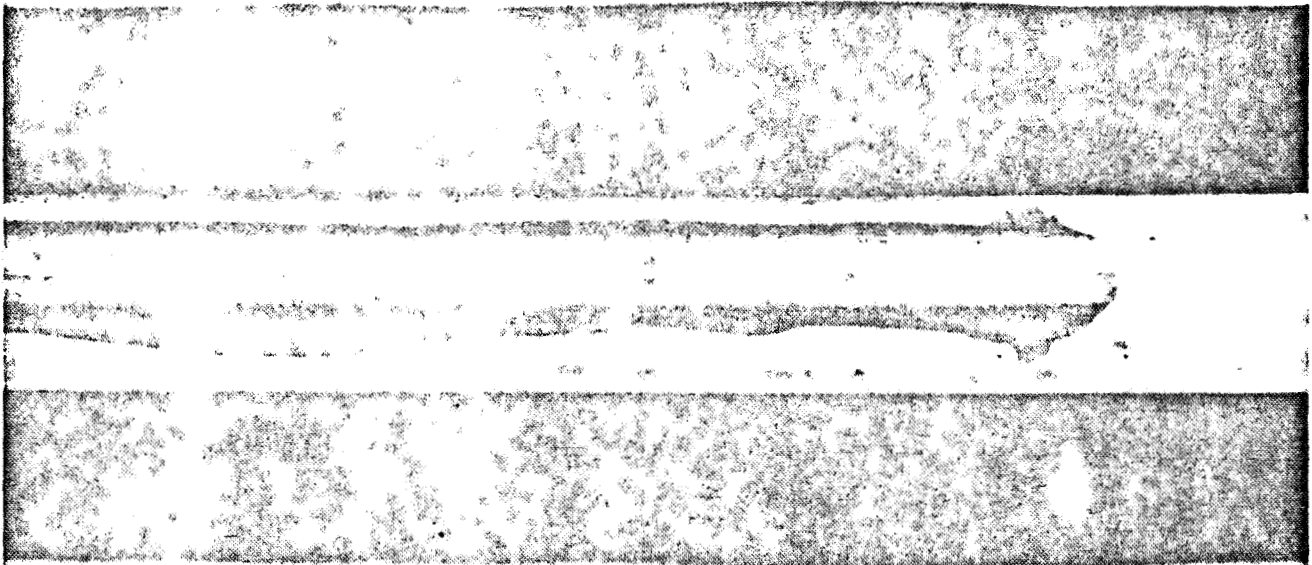


Figure 2-4. Excess Turco 5361 Paste-Etch Removed



6. Neutralize the surface by rinsing the etched area using cheesecloth dampened with deionized water taking care to remove all traces of the paste-etch. A multicycle rinsing operation is recommended to assure that all the potentially damaging chemical material has been completely removed.

NOTE: Adjacent areas are carefully examined for evidence of chemical attack or etchant residue resulting from spillage during handling or application.

7. Deoxidize the metal surface by wiping the etched areas using cheesecloth dampened with Diversey 514 solution (see Figure 2-5). Allow this deoxidizing solution to remain in contact with the surface from 2 to 5 minutes until the residual oxide smut is removed and the metal is brightened.
8. Wipe the Diversey 514 solution from the affected surface using clean, dry cheesecloth and rinse the area using cheesecloth dampened with deionized water. Again, take care to ensure removal of all traces of chemical residues.

NOTE Do not allow cheesecloth soaked with Diversey 514 to dry. Before disposing of cheesecloth contaminated in this manner, rinse all traces of Diversey 514 deoxidizer solution from the cloth with water so that the oxidizing chemicals in the solution will not cause the dried cheesecloth to ignite.

9. Verify the complete removal of chemicals from the affected areas by testing the treated surfaces with pH paper while the area is still wetted with water (see Figure 2-6). Rinsing with water is continued until the readings indicate the pH measures between 5.0 and 8.0, i.e., chemically neutral.
10. Check surrounding areas selected at random, particularly surfaces previously covered by tape maskants, using pH paper to verify the presence (or absence) of chemical spillage, splashes, or drops on adjacent surfaces and parts (see Figure 2-7). Neutralize any such areas immediately using cheesecloth dampened with deionized water. Repeat the rinsing sequence until surfaces are determined to be free from chemical contamination.



Figure 2-5. Deoxidization of Surface Using Diversey 514 Solution

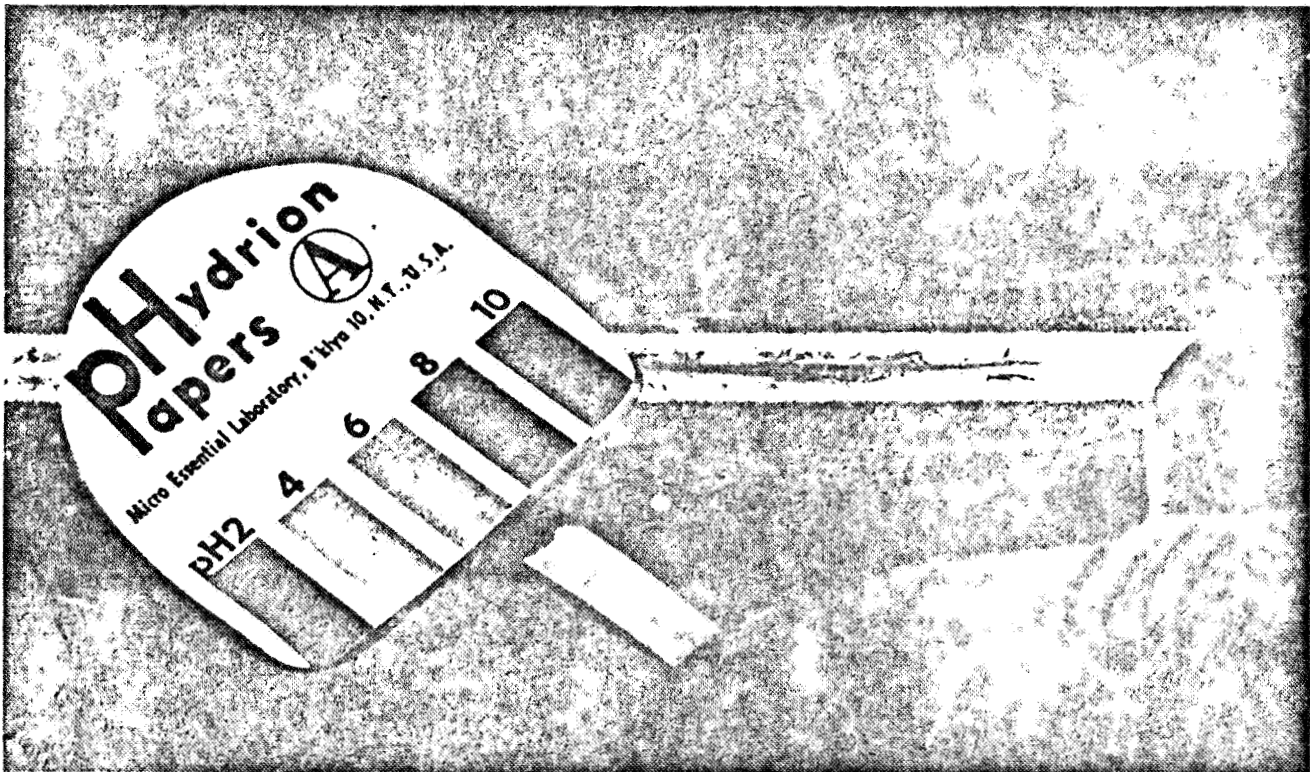


Figure 2-6. Testing Treated Surface With pH Paper

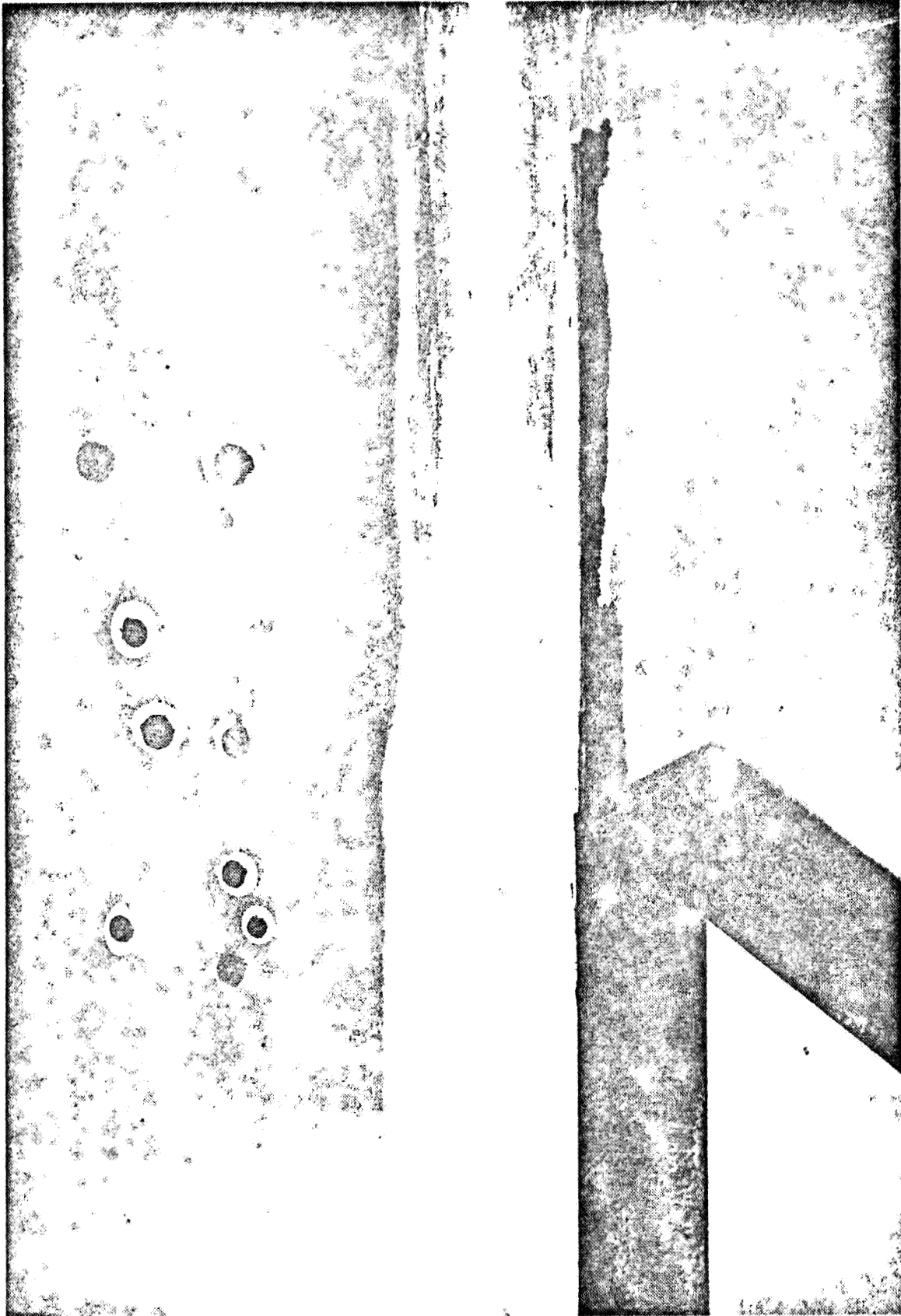


Figure 2-7. Chemical Etchant Spillage and Residue Under
Tape Maskant



NOTE: AppH measuring greater than 8.0 (alkaline) indicates that Turco 5361 paste-etch is contaminating the zone, and a pH reading of less than 5.0 (acidic) indicates that Diversey 514 deoxidizer is still present.

11. Wipe the dampened areas with clean, dry cheesecloth and allow the cleaned surfaces to air-dry at ambient conditions.

2.2.2 CHEMICAL-ETCH CLEANING OF STEEL ALLOYS PRIOR TO FLUORESCENT-PENETRANT INSPECTIONS

In special, infrequent cases the etching of steel alloys for removal of metal films is required prior to performing fluorescent-penetrant inspections. To accomplish such sequences, the following guidelines are employed

1. For ferrous steel alloys, etch in accordance with MA0110-012, "Cleaning Ferrous Alloys."
2. For corrosion-resistant steel alloys (CRES), etch in accordance with MA0110-013, "Descaling and Passivation of Corrosion and Heat-Resistant Alloys."

Before initiating etching sequences on steel parts, the Material and Process (M&P) Laboratories are contacted in all cases regarding the proper formulations and precautionary handling techniques required for the use of these hazardous chemical (acids) solutions.

2.2.3 INSPECTION PROCEDURE FOR NON-LO₂ WETTED SURFACES (see Figure 2-8)

Required Materials

1. Fluorescent penetrant P-149
2. Emulsifier E-153
3. Wash Deionized water and cheesecloth or other approved wipe cloth
4. Developer D-495A
5. Trichloroethylene

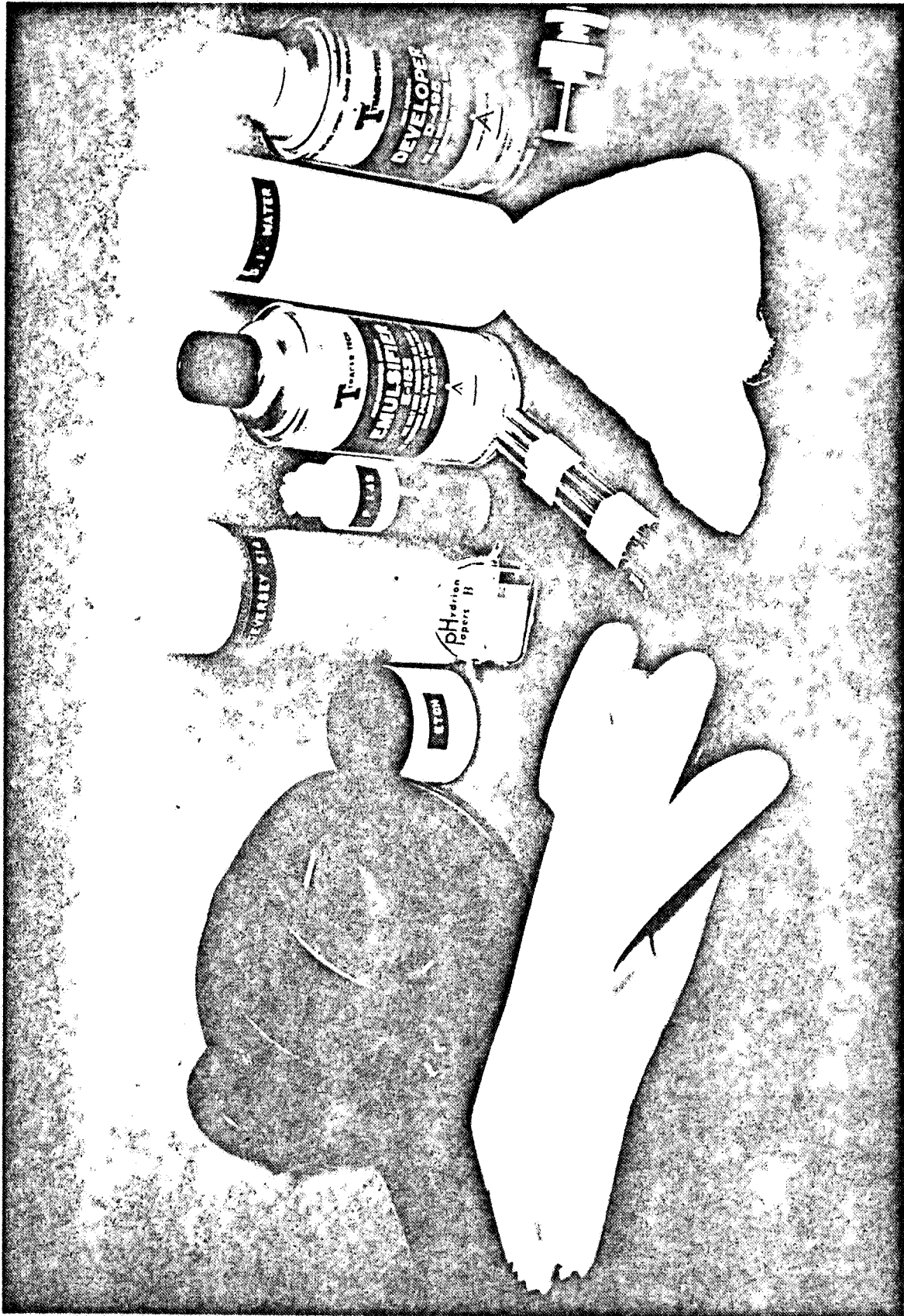


Figure 2-8. Fluorescent-Penetrant Materials for Non-LO₂
Wetted Surfaces

The following sequence is employed:

1. Wipe the area to be inspected using cloth dampened with trichloroethylene conforming to the requirements of NR SD Material Specification MB0210-003.
2. Apply fluorescent penetrant P-149 to the area being inspected using a clean acid brush or a 1-inch paint brush (see Figure 2-9). After applying the penetrant, check the area under black-light excitation to assure that complete coverage of the penetrant has been accomplished.

NOTE: The area being examined must be verified to be dry and free of any contaminants before the application of penetrant materials.

3. Allow a penetrant dwell time of 15 minutes (minimum).
4. Remove the bulk of the surplus penetrant from the surface using an approved clean, dry wipe cloth (see Figure 2-10).
5. Apply emulsifier E-153 over the penetrant by spraying from an aerosol can dispenser (see Figure 2-11). Allow an emulsifier dwell time of 2 to 5 minutes.
6. Remove the bulk of the surplus emulsified penetrant from the surface by wiping in one direction only using clean, dry cheese-cloth.
7. Remove the remainder of the surplus emulsified penetrant from the surface by wiping in one direction only, using a wipe cloth dampened with deionized water followed immediately by wiping the area dry using clean, undampened wipe cloth.
8. Repeat this entire inspection sequence if observation under black-light excitation indicates that all the excess penetrant has not been removed. In this case, utilize a slightly longer emulsification time.

NOTE: Do not repeat only the emulsification sequence in order to effect the satisfactory removal of surplus material.

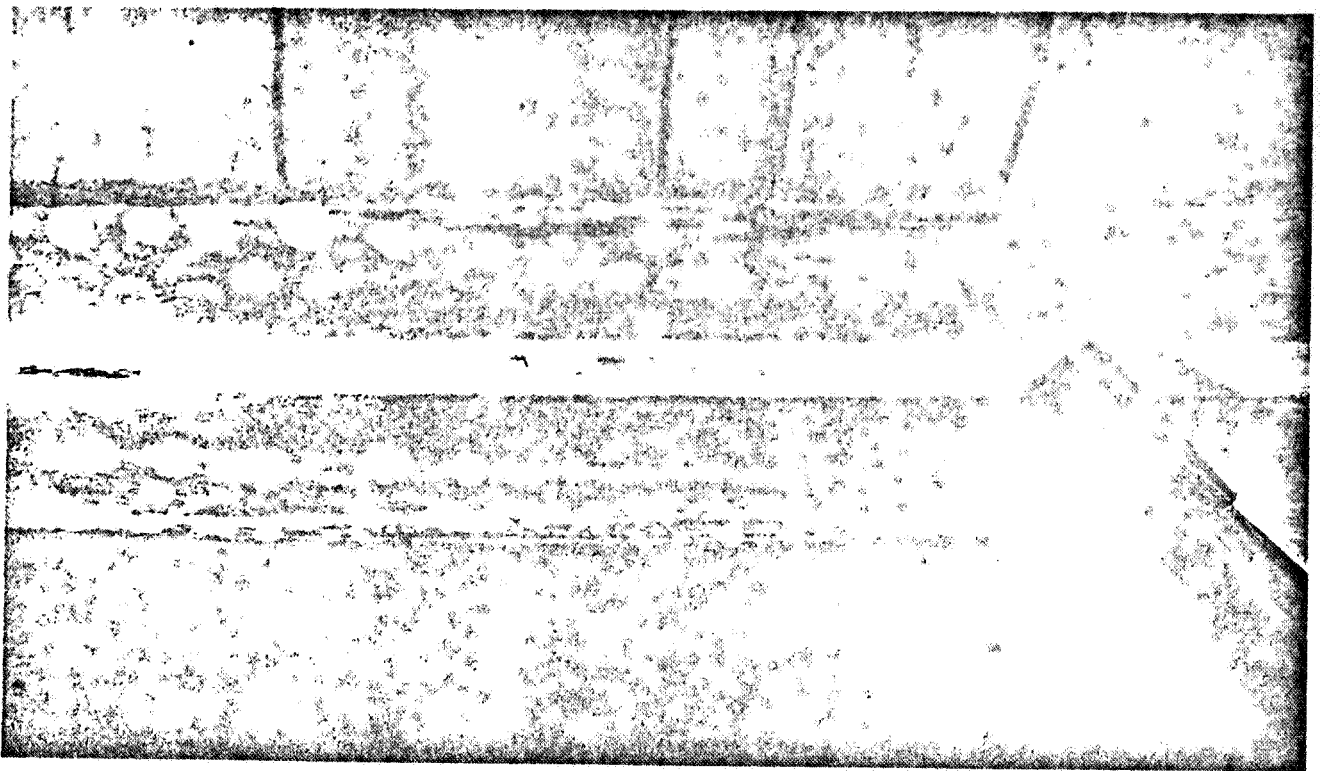


Figure 2-9. Application of Fluorescent Penetrant

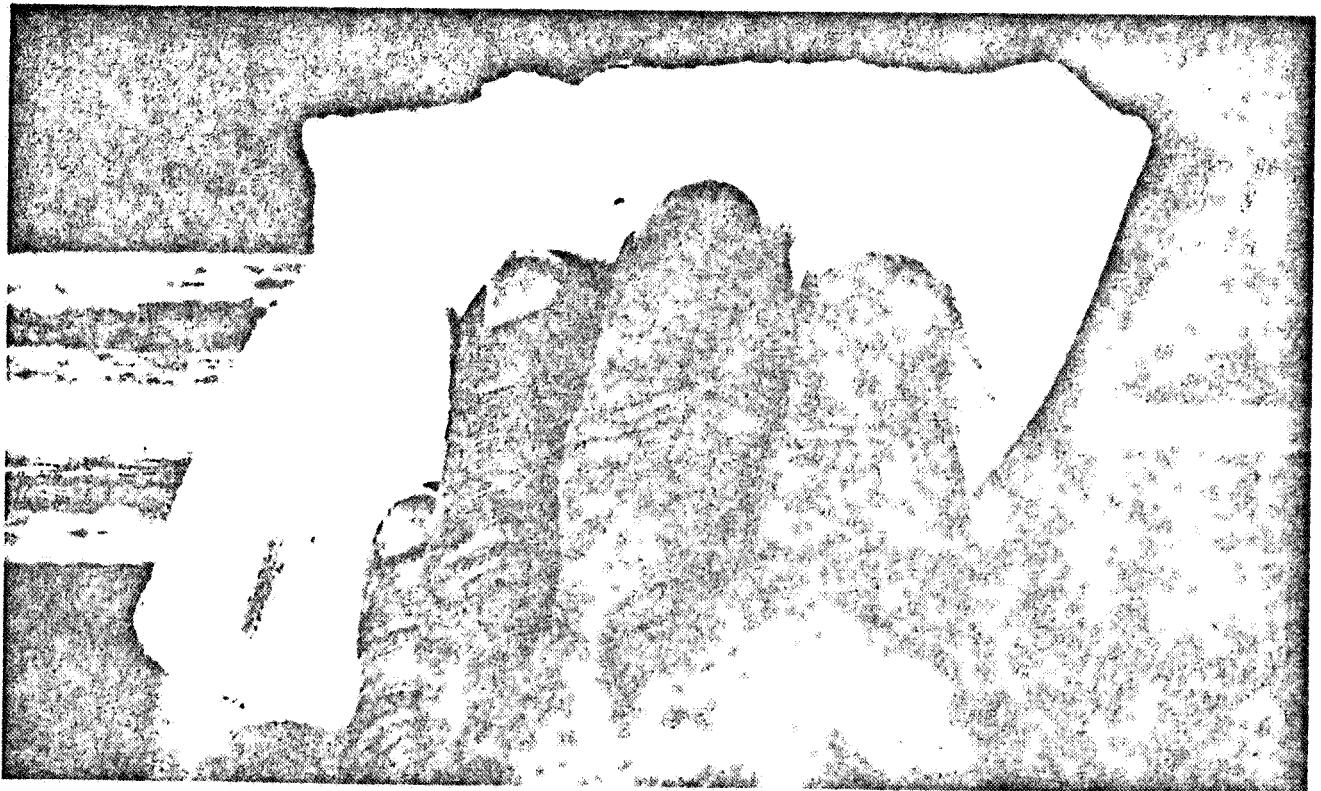


Figure 2-10. Removal of Surplus Penetrant

9. Apply a light, even coat of Developer D-495A by spraying from an aerosol can dispenser (see Figure 2-12). Allow the developer to remain on the surface for 5 minutes (minimum), but no longer than 2 hours.
10. Inspect the zone under black-light excitation (see Figure 2-13) and evaluate all indications in accordance with the acceptance criteria defined in the applicable NR SD process specification. A 7- to 10-power magnifying lens is used as required by inspectors to evaluate defective indications detected with the fluorescent-penetrant.

NOTE Black-light evaluation of the area being inspected should be conducted in a darkened area or enclosure. This is accomplished with curtains or hoods if the overhead lighting in the inspection area cannot be reduced (see Figure 2-14).

11. Clean and dry all areas exhibiting residual fluorescent material after completing the inspection evaluation. Usually, trichloroethylene conforming to the requirements of Specification MB0210-003 is employed. Verify the complete removal of all fluorescent-penetrant materials by examination under ultraviolet and white light.

2.2.4 INSPECTION PROCEDURE FOR LO_2 WETTED SURFACES (See Figure 2-15)

Required Materials

1. Non- LO_2 Reactive Fluorescent Penetrant P-545
2. Remover K-410A
3. Developer D-495A

The following sequences are employed for this application

1. Wipe the area to be inspected using cloth dampened with trichloroethylene conforming to the requirements of Material Specification MB0210-003.

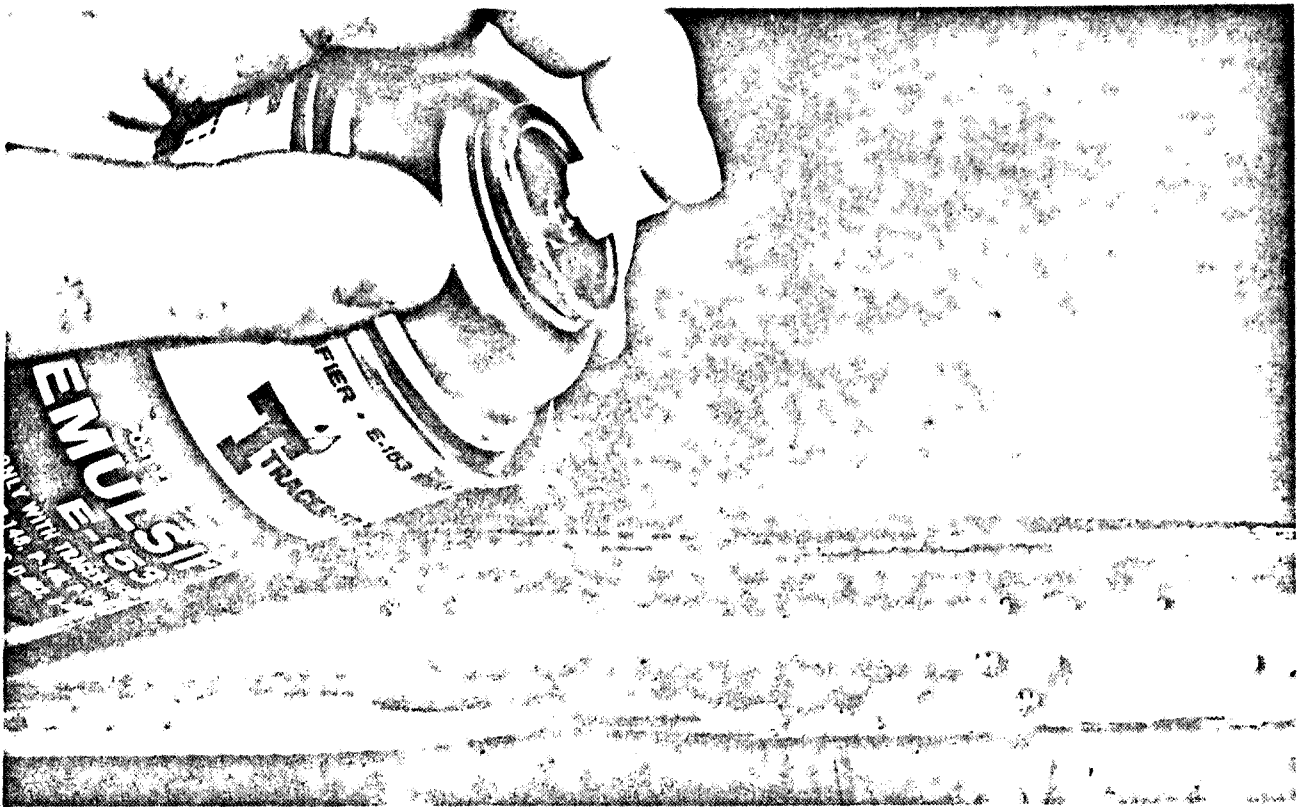


Figure 2-11. Application of Emulsifier E-153



Figure 2-12. Application of Developer D-495A



Figure 2-13. Black-Light Evaluation

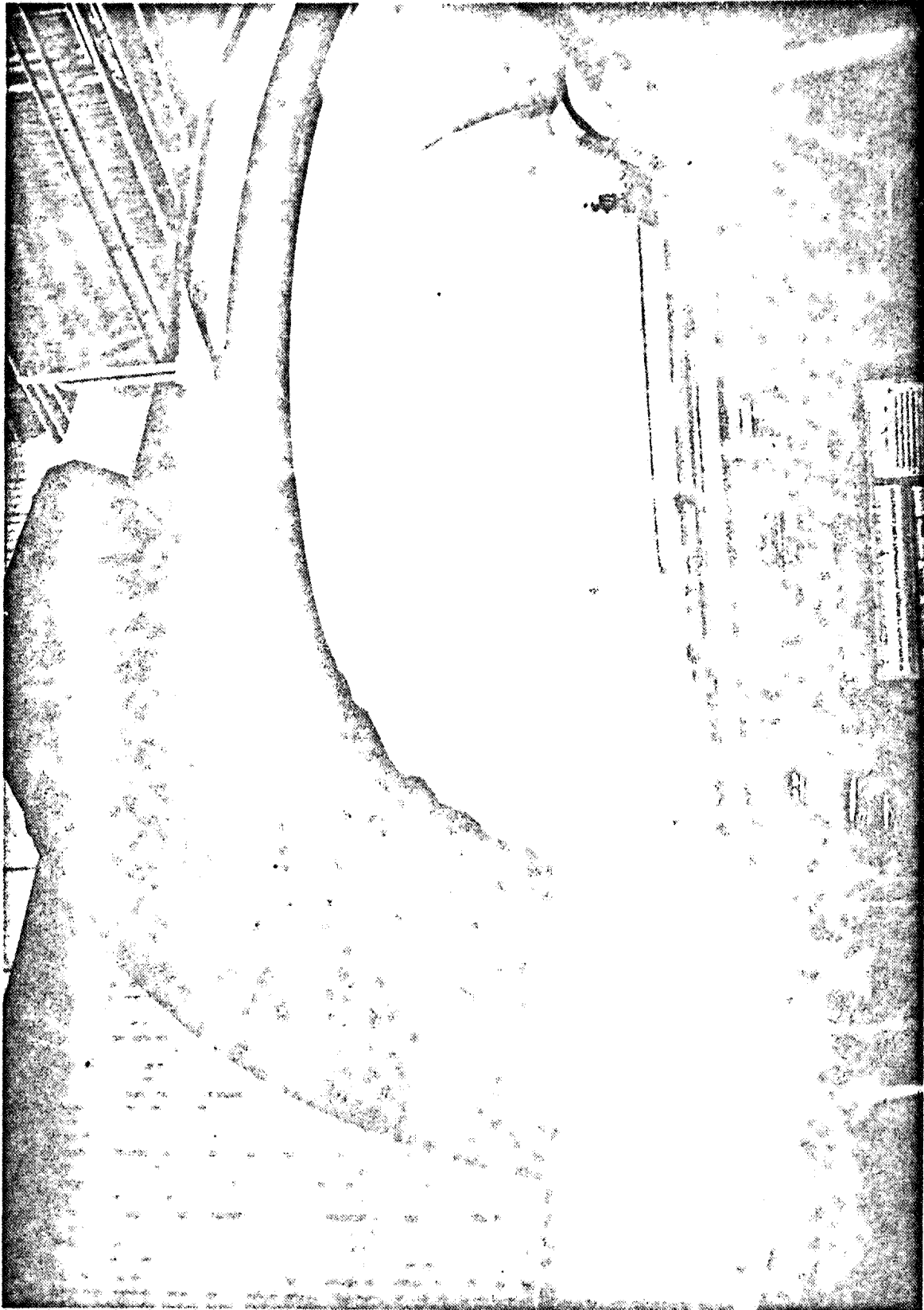


Figure 2-14. Hood-Darkened Area for Black-Light Evaluation

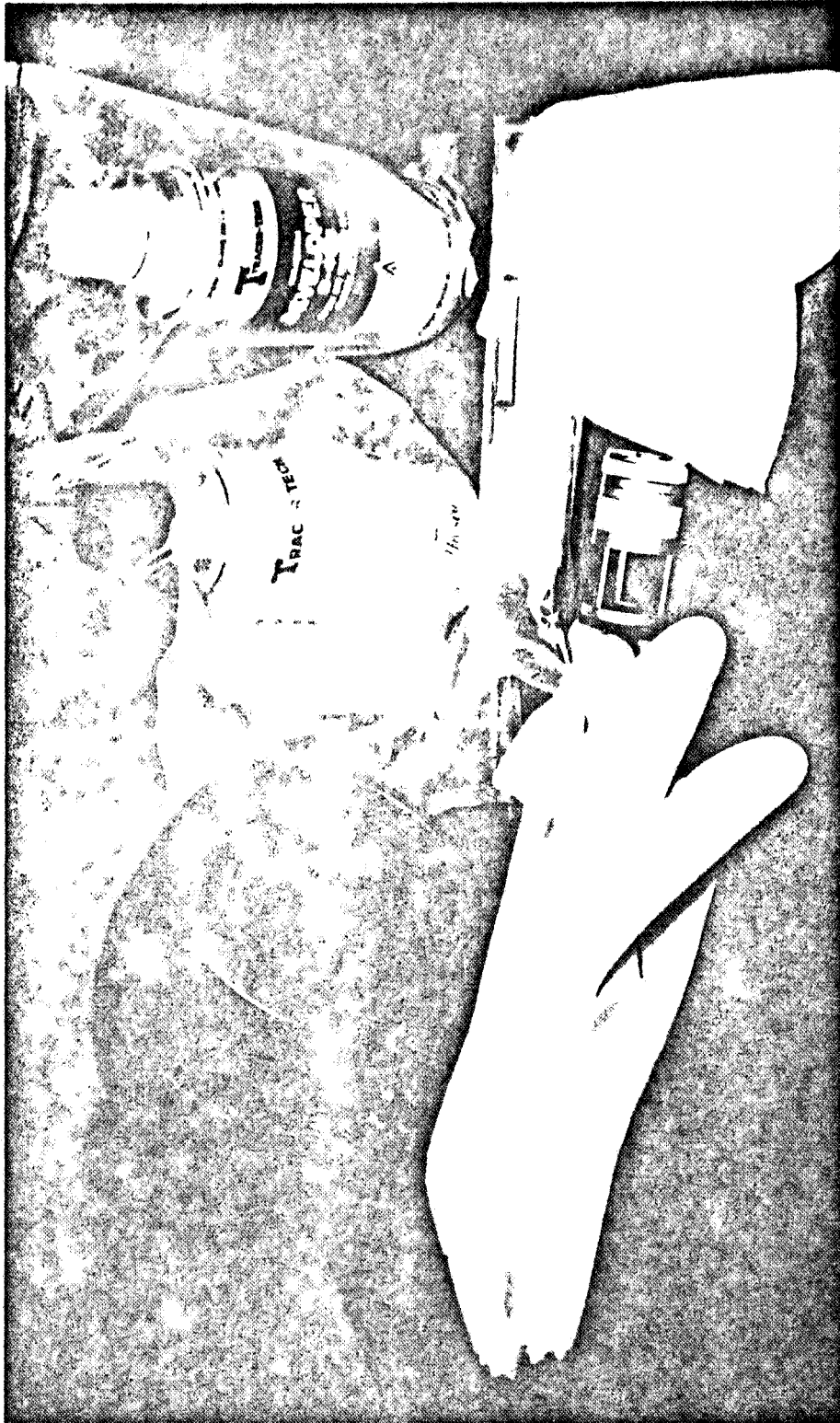


Figure 2-15. Fluorescent-Penetrant Materials for LO₂ Wetted Surfaces



2. Apply fluorescent penetrant (P-545) to the area being inspected using a clean acid brush or a 1-inch paint brush. After applying the penetrant, check the area under black-light excitation to assure that complete coverage of the penetrant has been accomplished.

NOTE. a. The area being examined must be verified to be dry and free of any contaminants prior to the application of penetrant materials.

- b. When applying the P-545 material to a surface, the proper amount of penetrant must be poured from the bulk container into a smaller container that has been properly cleaned, bagged, and protected from contamination (see Figure 2-14). Under no circumstances will the applicator be dipped into the bulk container or the unused portion of the material in small containers be returned to the bulk container.

3. Allow a penetrant dwell time of 5 to 10 minutes.
4. Remove all surplus penetrant from the surface by wiping in one direction only using an approved wipe cloth dampened with remover K-410A. Check the area under black-light excitation to assure that satisfactory removal of surplus material has been accomplished.

NOTE Clean, dry cheesecloth may only be used for removing LO₂-compatible, Class 5, fluorescent penetrant prior to cleaning S-II parts and assemblies for LO₂ service. After such cleaning the Class 5 penetrant is removed with a contamination-free wipe cloth that has been previously approved for use on LO₂ system parts by Engineering or the M&P laboratories.



5. Apply a thin, even coating of nonaqueous, wet developer D-495A using an aerosol can dispenser.
6. Allow a development time of 5 minutes (minimum) and 2 hours (maximum).
7. Inspect the zone under black-light excitation and evaluate all indications in accordance with the acceptance criteria defined in the applicable process specification. A 7- to 10-power magnifying lens is used as required by inspectors to evaluate defective indications detected with the fluorescent penetrant.

NOTE: Black-light evaluation of the area being inspected is conducted in a darkened area or enclosure. This can be accomplished with the use of curtains or hoods if the overhead lighting in the inspection area cannot be reduced.

NOTE The majority of fluorescent penetrants observed under black-light excitation appear yellow-green in color. The P-545 LO₂ compatible penetrant appears blue-white in color.

8. Clean and dry all areas exhibiting residual fluorescent penetrant materials after completing the inspection evaluation, using the specified type of wiping material dampened with trichloroethylene conforming to the requirements of Specification MA0210-003.

2.2.5 FLUORESCENT-PENETRANT INSPECTION OVER CHEMICAL-FILM-TREATED SURFACES

After completing all welding operations and nondestructive testing sequences, the exposed bare aluminum surfaces are treated with a colored chemical conversion coating (Chem-Film) to protect the material from corrosion during subsequent service. The Chem-Film is present on weld zones of structures which require fluorescent penetrant inspection after pressure cycles, i. e., hydrostatic and pneumatic tests (see Figure 2-16). This protective covering is not removed by chemical etching, abrading, etc., for the purpose of performing such fluorescent-penetrant inspections.

If rework by grooving or rewelding of discrepancies is subsequently required, then only the affected repair area is re-etched to accommodate additional standard penetrant inspections.



Figure 2-16. In-Tank Fluorescent-Penetrant Inspection Over Chem-Film



NOTE: Cheesecloth is not used for penetrant operations performed after pneumatic testing because of emission of lint. Only laboratory-approved cloths that do not emit lint will be used to perform post-test inspection.



3.0 ULTRASONIC INSPECTION PROCESSES

This section describes the methods and procedures used to inspect common bulkheads and aft LO₂ bulkhead dollar welds through the use of ultrasonic techniques. The common bulkhead is inspected through the use of both through-transmission and pulse-echo methods, while the aft LO₂ bulkhead dollar weld is inspected by using the shear wave method. Each method is explained in detail in this section, and considerable emphasis is placed on the method used to inspect the common bulkhead because of the unique aspects of the equipment and the complexity of the actual inspection procedure.

3.1 COMMON BULKHEAD INSPECTION

The common bulkhead is a unique adhesive-bonded sandwich assembly. The assembly is inspected for bonding integrity on a special tool specifically designed to accommodate this assembly. This special tool uses through-transmission and pulse-echo ultrasonic methods to evaluate the bonding integrity and is equipped with a "C" scan recording system to facilitate evaluation and produce a permanent record of the inspections. The ultrasound is transmitted through the bulkhead structure by synchronized squirter nozzles rather than by the most commonly used submerged method.

This specialized inspection system has a centerless turntable that is operable over a continuous speed range for rotating the parts, two sets of inner and outer transducer support assemblies for positioning the transducers for a through-transmission or pulse-echo inspection, a model turntable synchronized with the part holding turntable, a printer support assembly with the printer stylus synchronized with the outer transducer tape program, and console-mounted electronic instrumentation. The instrumentation includes the logic and control circuitry for positioning the transducers and printer stylus throughout an entire inspection, safety circuits to minimize the hazard of damaging a part of the system because of a malfunction or operating error, a tape reader and spooler, an 824D immerscope, an MK-7 flaw detector with gate adapter, and an SR-130 recorder adapter to generate model recording voltages.

3.1.1 SYSTEM DESCRIPTION

Transducer and Printer Assemblies

Transducer Carriage Support Column Assemblies

Four transducer carriage support columns are provided for guiding the carriage and transducer assemblies in a vertical plane which intersects the turntable axis.

Outer Bulkhead Column. The outer bulkhead column assembly (Figure 3-1) has two straight line element guide tracks that are tangent to a common bulkhead surface. The column is rigidly mounted to a support boom which pivots about a vertical axis to permit alignment for a bulkhead inspection or positioning to a standby location (see Figure 3-1). A manual handcrank at the base of the structure assists in locating the boom in place (see Figure 3-2).

The column straightline elements have gear racks which mesh with the carriage position drive (see Figure 3-3). A transfer table extends either straightline element to transfer the transducer carriage from one element to the other (see Figure 3-4). The transfer table is described later in this section.

Inner Bulkhead Column. The inner bulkhead column (Figure 3-5) resembles the outer bulkhead column except that the support structure on the inner column is rigidly lagged to the concrete floor.

Printer Carriage Support Column Assembly

One printer carriage support column assembly (Figure 3-6) is supplied to position the printer carriage at the same attitude as the bulkhead transducer carriage. The printer carriage support column consists of one straightline element that may be pivoted to three stations:

1. Parallel to the upper bulkhead column
2. Parallel to the lower bulkhead column
3. Vertical

The column support assembly is rigidly mounted to the outer column, recorder table, and drive element. The column is equipped with a guide track and printer carriage gear rack.

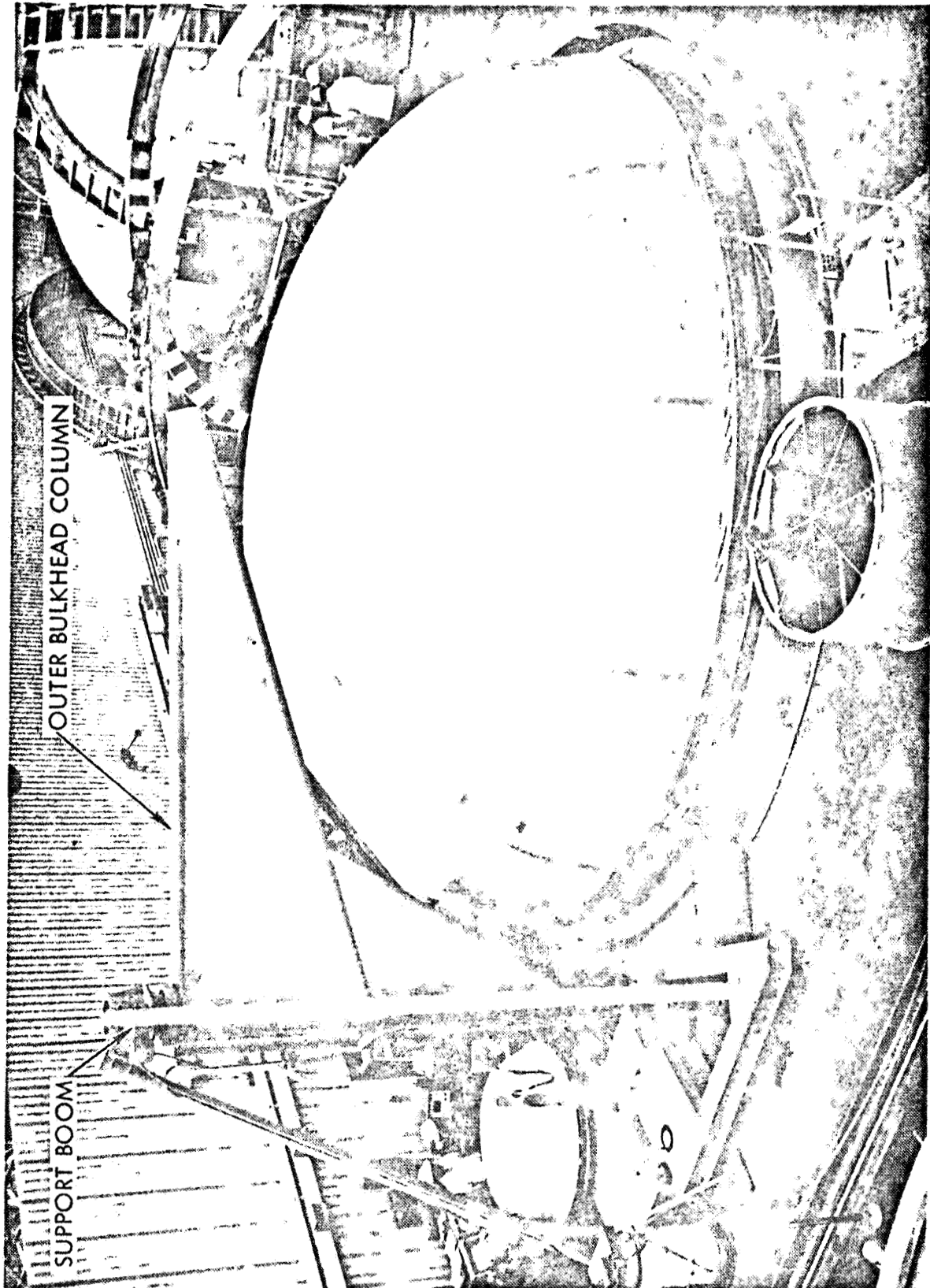


Figure 3-1. Overall View of Automated Ultrasonic Inspection System

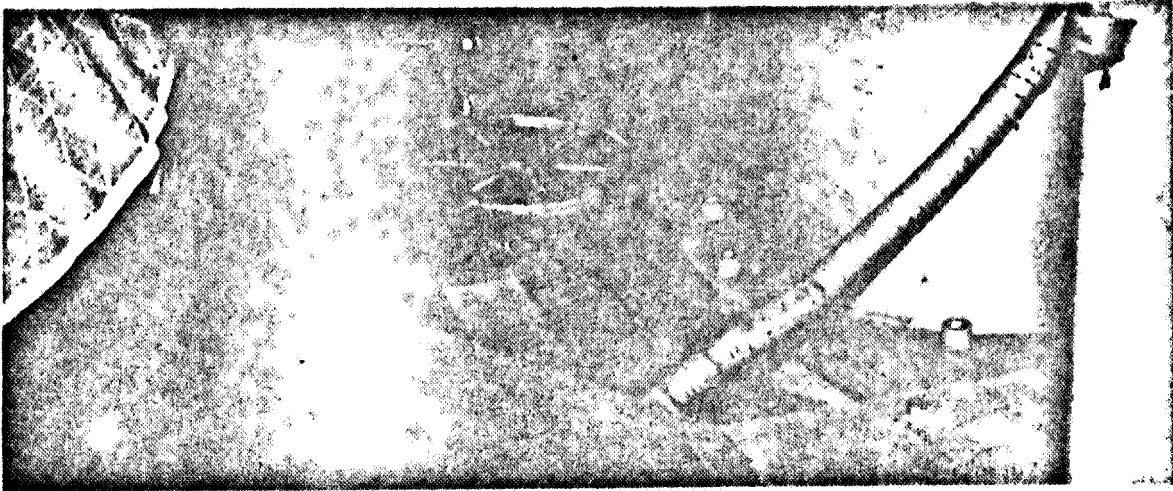


Figure 3-2. Outer Column Manual Handcrank

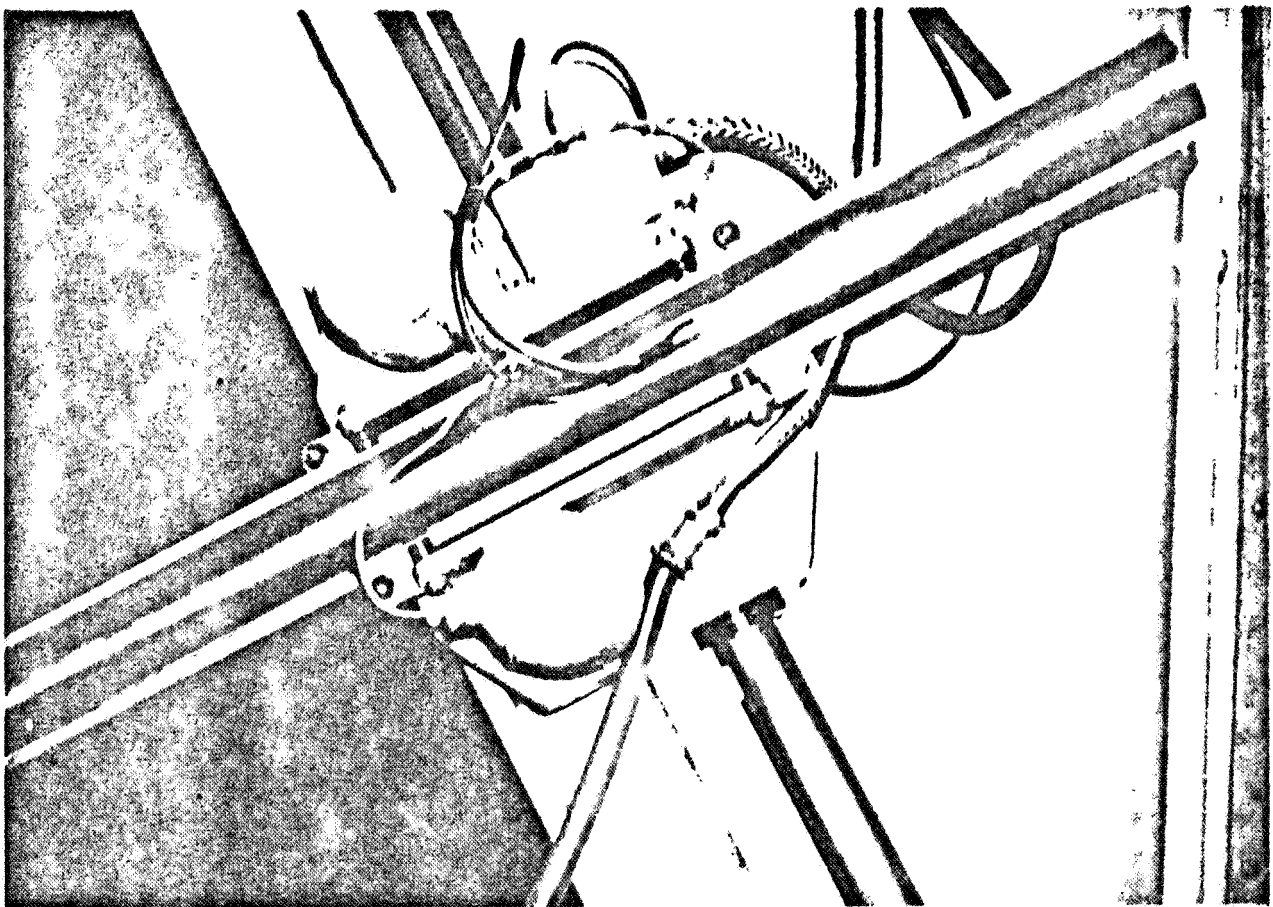
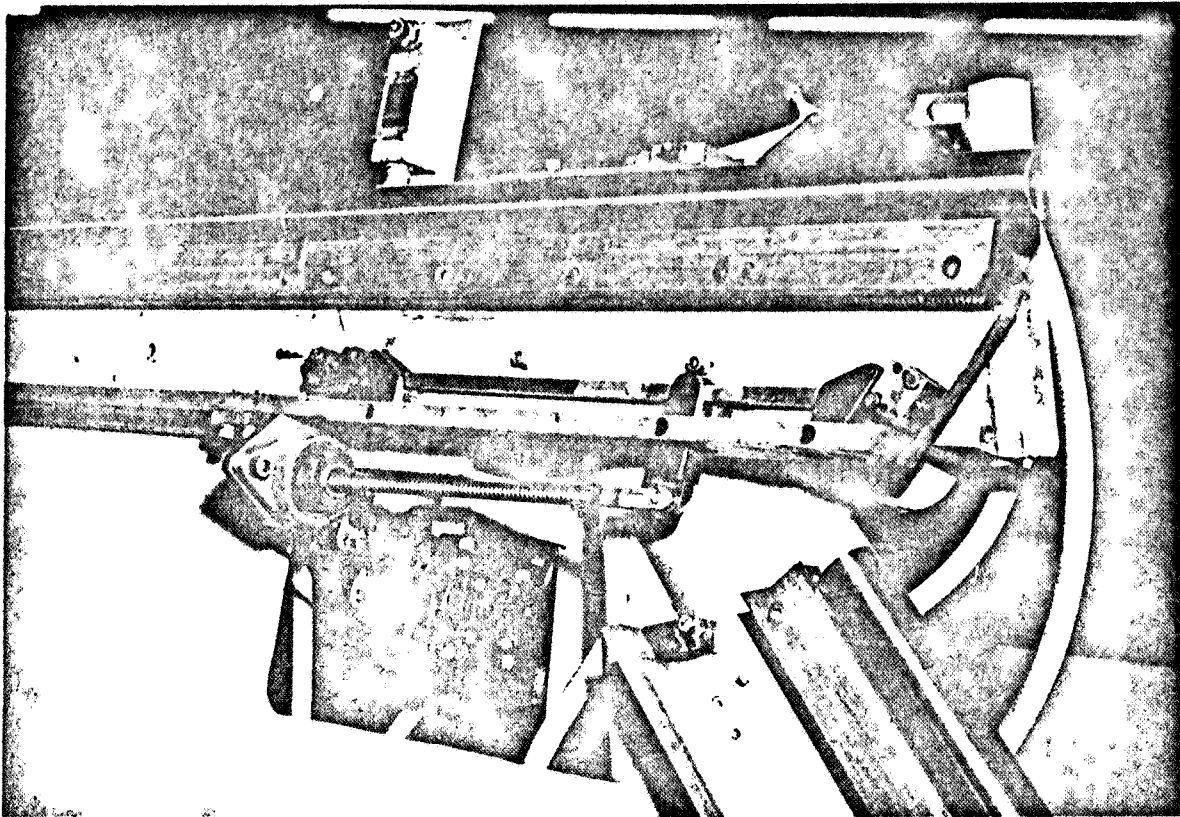
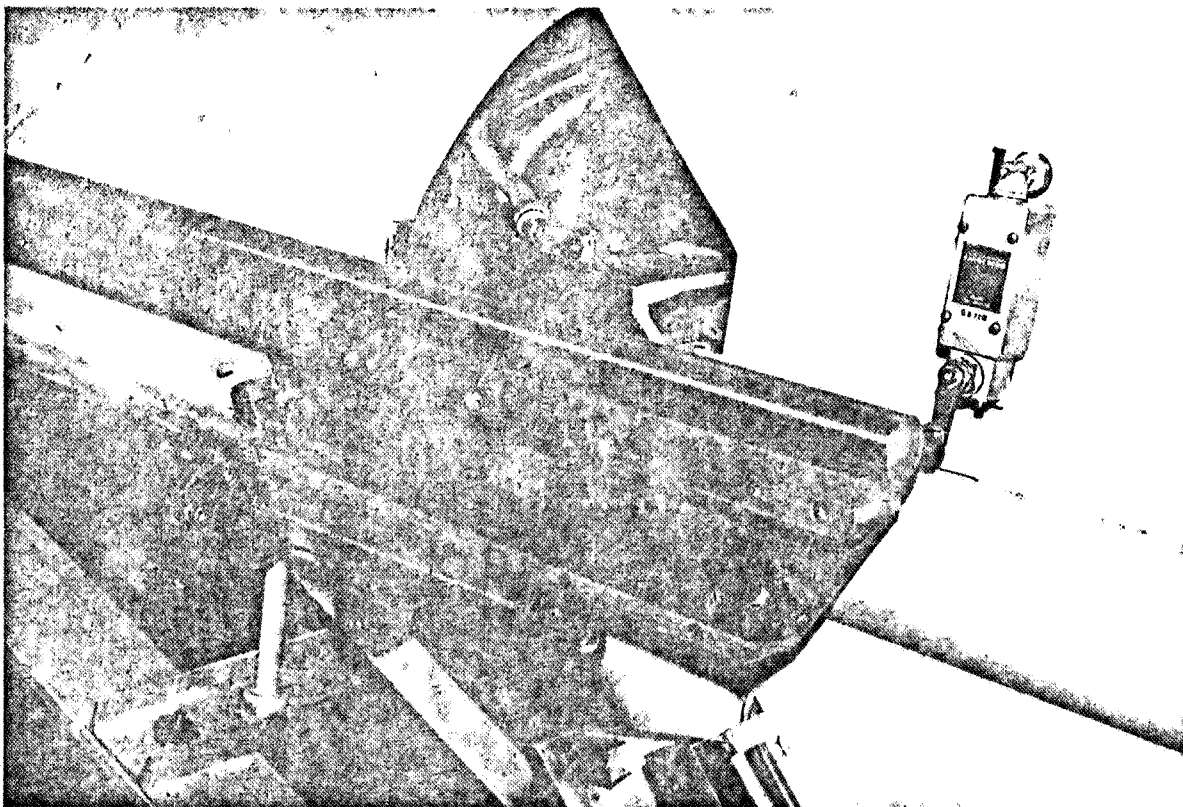


Figure 3-3. Transducer Carriage Mechanism



INNER TABLE



OUTER TABLE

Figure 3-4. Carriage Transfer Tables

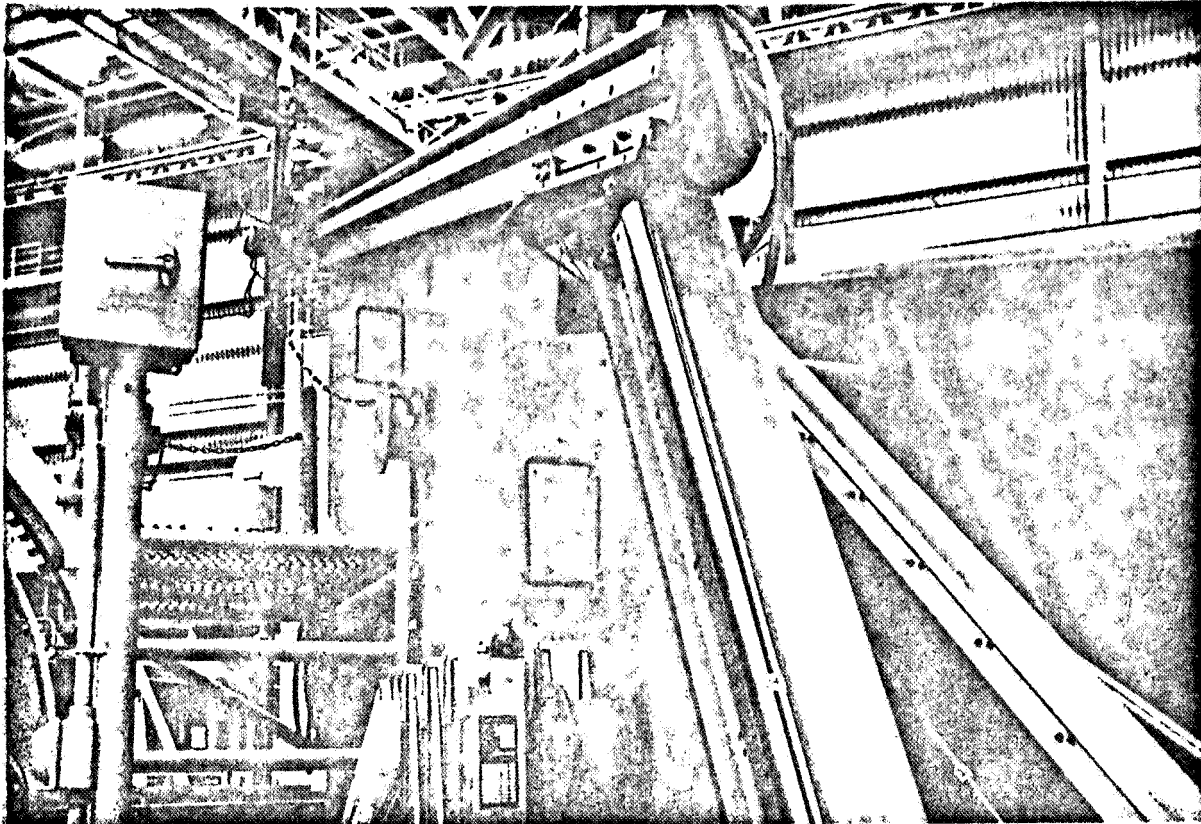


Figure 3-5. Inner Bulkhead Column

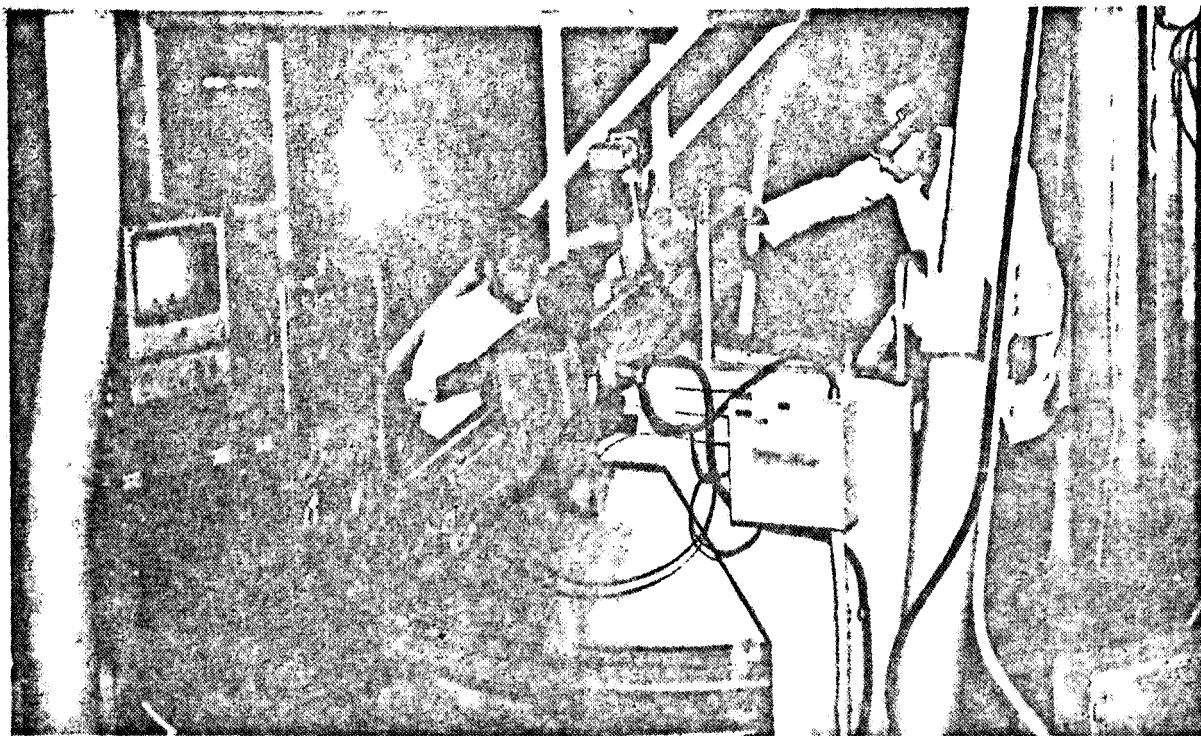


Figure 3-6. Printer Assembly

Transducer Carriage Assemblies

Transducer carriages position the transducer parallel and perpendicular to the column guide tracks. The inner and outer bulkhead carriages are constructed identically. (See Figure 3-3.)

The carriages are positioned parallel to the column guide track in 0.002-inch steps. The position drive may be jogged or slewed at a rate to 50 steps per second. The carriages position the search tubes perpendicular to the guide track in 0.005-inch steps. This axial positioning may be jogged or slewed at a rate to 50 steps per second.

Printer Carriage Assembly

The printer carriage closely resembles the transducer carriage in function and construction with the prime exception that the displacement is reduced by a factor of 5. The carriage displacement is limited to 0.0004 inch per step. The motion may be jogged or slewed to 50 steps per second.

The stylus support tube displacement is limited to 0.001 inch per step. The displacement may be jogged or slewed to 50 steps per second.

Transducer Angle

Transducer angle drive assemblies are provided for gimbaling the transducer, with respect to the search tube support axis, in the vertical plane. All angle drives are constructed identically (see Figure 3-3).

The transducer angle is positioned in 5-minute steps and may be jogged or slewed to a rate of 50 steps per second.

Stylus Angle

The stylus angle drive closely resembles the transducer angle drive and provides the same positioning function. The stylus angle is positioned in 5-minute steps and may be jogged or slewed to a rate of 50 steps per second.

Transfer Tables

Two transfer tables (Figure 3-4) identically constructed are supplied for transferring the bulkhead carriages from either straight-line element to the other. Each has a guide track and gear rack to mate with the column guide track and gear rack, one tilt drive motor, and five limit switches to permit proper carriage positioning on the table and proper table tipping direction.

Two safety limit switches reverse the carriage index direction when the carriage advances toward the transfer-table end not mated with the column guide track and gear rack.

Two limit switches terminate the transfer table tilt motion and also set the tilt drive direction.

A tilt switch indicates when the carriage being positioned is in the center of the transfer table. Table tilting cannot be initiated unless the carriage is centered.

As a safety feature, no stepping motor can be run until either transfer table tilt limit switch is activated. This ensures that the transfer tables are engaged when the carriage is stepped onto the column guide track.

Turntable Assemblies

Bulkhead Turntable

The turntable assembly drive is a 5-hp, 440-vac, 60-cycle Reeves variable-speed drive with a 2-speed starter control. A handwheel for manual turntable positioning is located at the output shaft of the Reeves varidrive (see Figure 3-7). The angular drive then is reduced by a 10:1 right-angle gear box and rotates the double-row roller-chain sprocket.

A double-row steel chain, approximately 100 feet long, couples the drive motion to the centerless turntable. Twenty-four McGill cam followers with a nominal thrust rating of approximately 8000 pounds are used to support the turntable on the turntable rack. Identical followers are used to radially position the face plate.

Model Turntable

The model turntable (Figure 3-6) has a single-row steel-chain drive mechanically synchronized with the part turntable.

Model Turntable Limit Switch

The limit switch (LS-1) is activated by a switchman located on the model turntable, which initiates the transducer index once every turntable revolution. Limit switch water shutoff (LS-WS) is activated by adjustable switchmen located on the model turntable. The switch closure initiates a command to energize the water squirter's shutoff valve.

NOTE: This provision is not used when the bulkhead is installed.

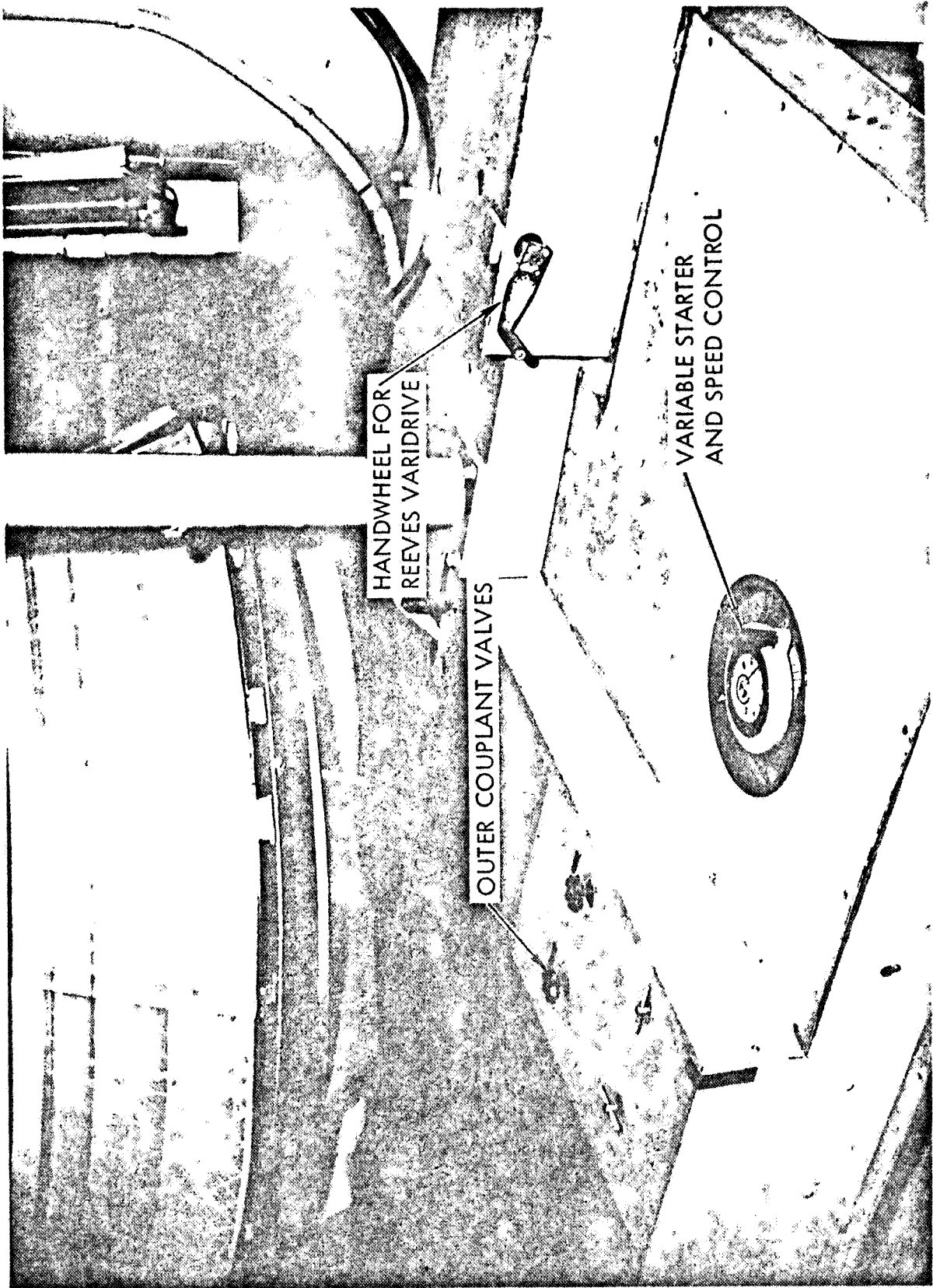


Figure 3-7. Outer Water Pressure Regulators and Turntable Drive Controls

Water Assembly

The water system is designed to supply filtered and recirculated water to the transducer squirter assemblies (Figure 3-8). The water system activation and flow direction is controlled by the console control panel. A 2-hp, 440-vac, 3-phase motor and pump supply water pressure is provided for the squirter assemblies.

A water bypass valve recirculates the pump water when excessive pressure builds up at the pump outlet. The bypass valve prevents damage to the pump and motor assembly because of the high head pressure that results when the flowrate is restricted.

Two 25-micron particle filters are connected to the pump outlet to filter the water at an adequate flowrate. One filter is associated with the inner water squirter assembly, and the other filter is associated with the outer water squirter assembly.

Two water pressure regulators are supplied, adjustable from 0 to 30 psi, for setting the water squirter water pressure. One regulator connects to the inner squirter filter (see Figure 3-9). The other regulator connects to the outer squirter filter (Figure 3-7).

Two solenoid valves direct the regulated water pressure output to the bulkhead transducer squirters. The position for cutoff of the valves is set by the operator. All valves are closed, which acts as a water shutoff valve to the squirters, when the LS-WS on turntable assemblies is activated. The water shutoff system is not used when the bulkhead is installed.

Console

The console is divided into four control functions: console control panel, translator control section, tape reader section, and the tape spooler. Each has an independent power control activated by a separate switch for its power supply. It is essential to the operator to have a complete understanding of each switch position on the console and its relationship within the system. The switch positions as labeled on the panels followed by a description of their control within the system are summarized in the following paragraphs.

Console Control Panel (See Figures 3-10 and 3-11)

Power: Applies 115 vac to the translator, tape reader, tape spooler, SR-130 recorder adapter, and sola regulator (see Figure 3-11).

Water Pump: Turns the recirculating water system on.

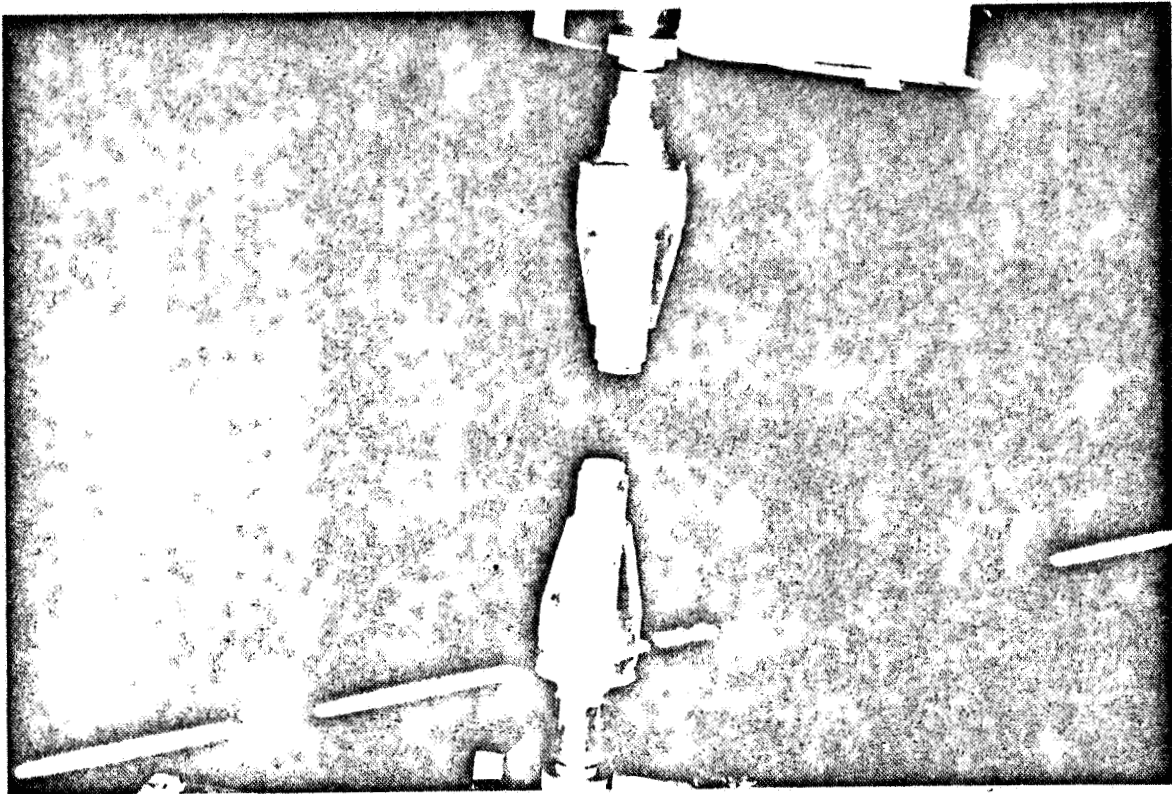


Figure 3-8. Water Couplant Nozzles

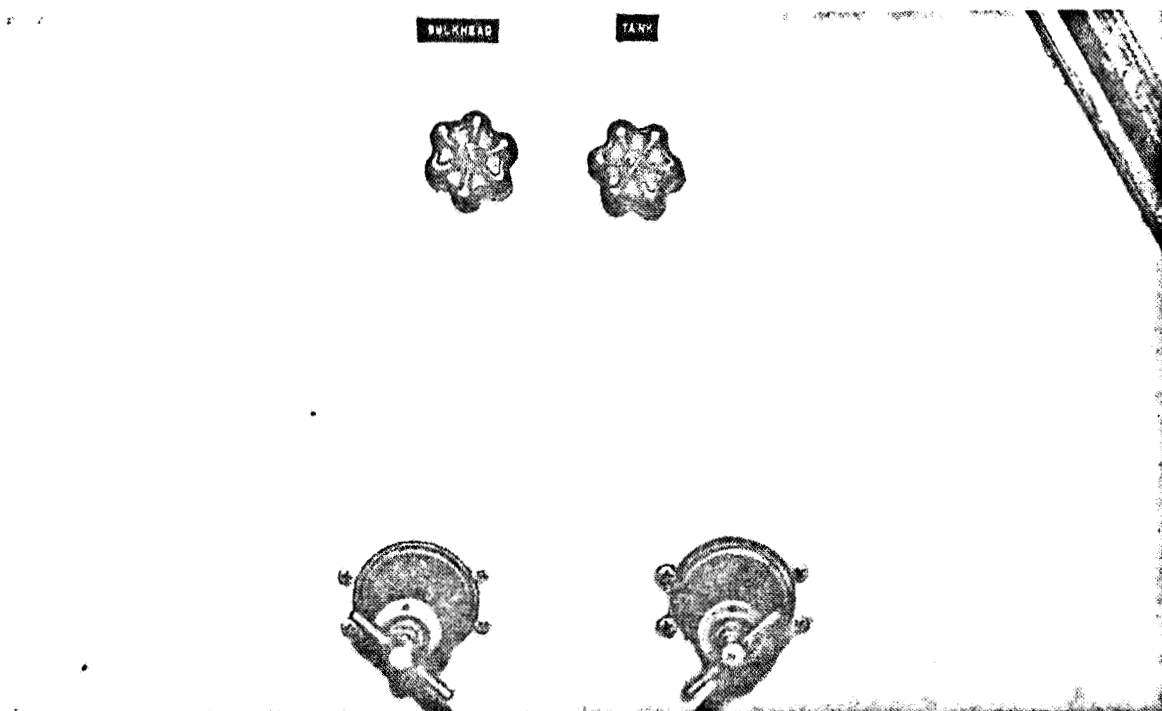


Figure 3-9. Inner Water Pressure Regulators

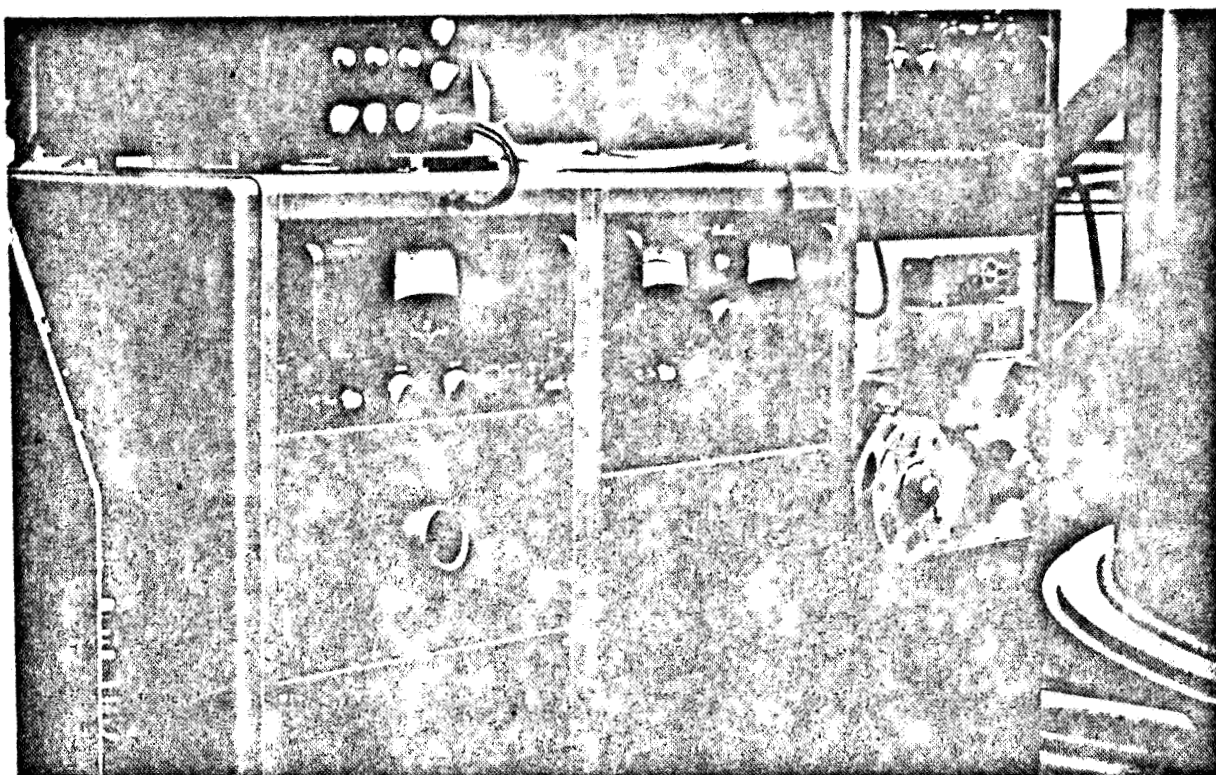


Figure 3-10. Overall Console Control Panels

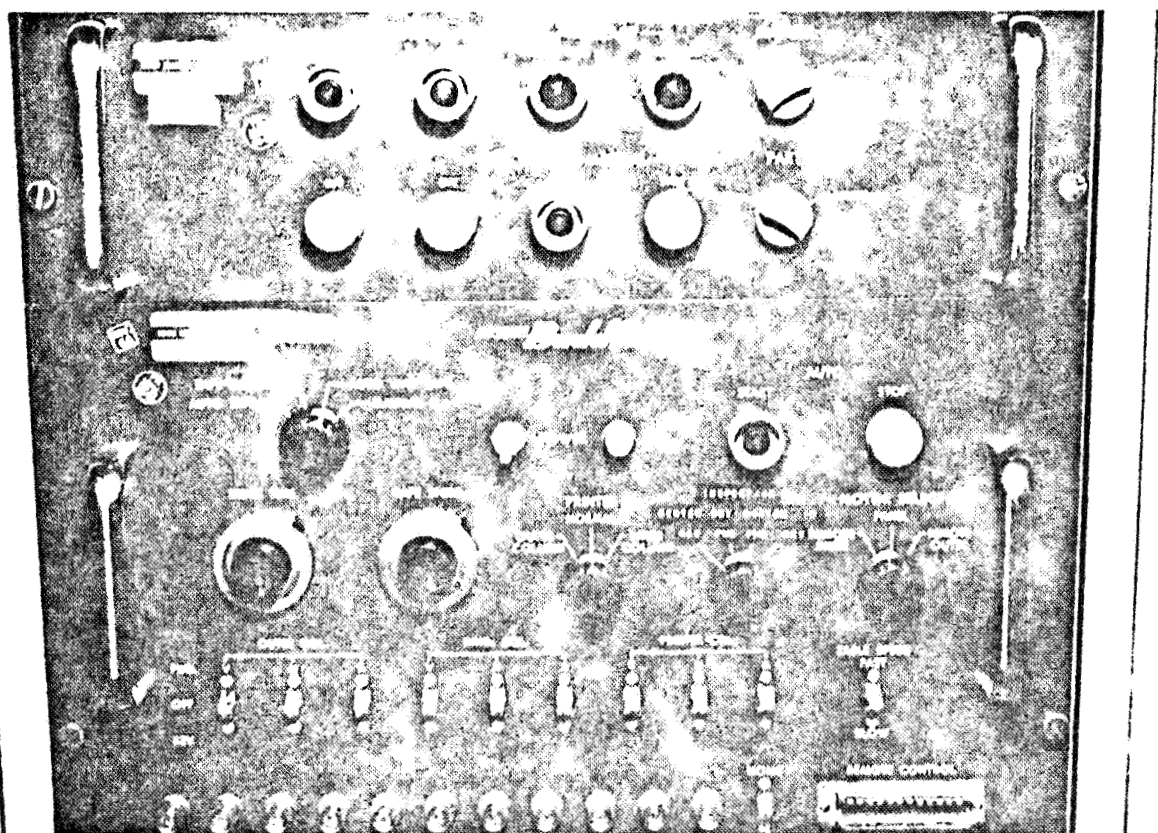


Figure 3-11. Main Control Console

Index Tables: Manual, readies the printer arm gimbal for manual positioning and readies the outer and inner column transfer tables for manual positioning.

Index Tables: Ready, indicates a readiness condition and proper outside carriage placement for manual positioning of outer and inner tables

NOTE: The following switch circuit activation requires prior positioning of index tables to "manual" position.

Start: Initiates CW or CCW tipping of the transfer table as set by the table location. When the table is between the limits, a CCW rotation is initiated.

Reverse Terminates tipping of the transfer table.

Bulkhead: Connects all motor and switches relative only to a bulkhead inspection (see Figure 3-11).

NOTE: Straight panels can be inspected in the tank position. The inspection of straight panels is not covered in this procedure

Translator (see Figure 3-11)

Power Applies power to the translator.

Automatic Start, Stop: Initiates and terminates automatic scanning.

Mode Switch "Manual": Permits manual control for an equipment setup.

Manual Tape: Permits the operator to run the tape, and all motors controlled by the tape, for a setup or reevaluation of a panel requiring tape control.

Automatic Without Tape Permits an automatic inspection of panels that have vertical or horizontal straightline elements, therefore not requiring a tape program.

Automatic Tape Permits a fully automatic tape-controlled inspection.

Motor Select Panel (See Figure 3-11)

1. Mode Switch in Manual: Any combination of the stepping motors associated with the bulkhead inspection may be run in the forward or reverse direction by appropriately setting the nine column toggle switches and remote box controls.
2. Mode Switch in Manual Tape: Tape may be jogged or slewed at an adjustable rate controlled by the remote control box button and the translator panel tape speed control. The nine panel motor select switches and other remote box controls are inoperative.
3. Mode Switch in Automatic Without Tape: The nine panel select switches select the nine stepping motors to be used and their stepping direction. The remote box button becomes a remote stop button. All other remote box controls are inoperative.
4. Mode Switch in Automatic Tape: Remote box button becomes a remote stop. The nine panel toggle switches and all other remote box controls are inoperative.

Remote Inner (see Figure 3-11)

1. Mode Switch in Manual: Individual stepping motors may be jogged or slewed at a remote control box rate, from the remote control box, in either the forward or reverse direction.
2. Mode Switch in Manual Tape: Tape may be jogged or slewed at an adjustably controlled rate that is initiated by the remote box button. This mode is used for a pulse-echo inspection setup of an inner bulkhead. All other remote box controls are inoperative.
3. Mode Switch in Automatic Without Tape: Remote control button becomes a remote stop button. All other remote box controls are inoperative.
4. Mode Switch in Automatic Tape: Remote button becomes a remote stop button. All other remote box controls are inoperative.

Remote Outer : (See Figure 3-11) This sequence is the same as items 1 through 4 of the remote inner position.

Inspection (See Figure 3-11)



Center Out (Forward-Reverse): Selects the proper stepping motor advance direction when an inspection of the upper bulkhead is desired.

NOTE: Always run in the forward position for an automatic inspection. Only run in the remote inner or remote outer manual tape position after an inner or outer transducer alignment. Only run in the panel, manual tape position after the transducers have been aligned for a through-transmission inspection.

Bottom In (Forward-Reverse): Selects the proper stepping motor advance direction when an inspection of the lower bulkhead is desired.

NOTE: Refer to note above.

Printer

Normal: Synchronizes the printer stylus stepping motor controlled axis with the outer carriage stepping motors for obtaining a through-transmission inspection recording.

Outer Column: Synchronizes the printer stylus with the outer transducer for obtaining an outer pulse-echo inspection recording.

Inner Column: Synchronizes the printer stylus with the inner transducer for obtaining an inner pulse-echo inspection recording.

Index Time: The control sets the index time initiated for each turntable revolution when the mode select switch is in either automatic position. The index time is variably controlled from approximately 0.2 to 5 seconds (see Figure 3-11).

Tape Speed: Adjust the slew rate, with or without tape, when operated in either automatic mode or the manual tape mode.

Forward-Off-Reverse: Permits the operator to select the inner, outer, or printer stepping motors, associated with positioning of the bulkhead, to be activated in the direction in which they are to run. The control is operable as indicated earlier (see Figure 3-11).

Remote Box: The remote box has the following stepping motor controls (see Figure 3-12)

1. **Jog Slew:** Selects a jog or slew operation of the stepping motors.



2. Forward-Reverse: Selects the direction of the stepping motor rotation.
3. Rate: Adjusts the stepping motor stepping rate in the manual mode.
4. Jog Button: Initiates stepping motor or tape jog or slew operation. The control is a remote stop button when operated in either automatic mode.
5. Motor Selector: Selects the motor to be operated.

NOTE: Refer to "Motor Select" discussion for a complete operation logic description.

Table Speed: The control is operable in the Motor Select-Panel position only. (See Figure 3-11.)

Fast: Increases the turntable speed and recorder current when properly tape programmed.

Slow: Decreases the turntable speed and recorder current when properly tape programmed.

NOTE

This switch has been deactivated.

Home-Step: Manually advances the logic sequence of the positioning controls for a transition during a bulkhead inspection (See Figure 3-11.)

Home: Steps the logic sequence to a start condition.

Step: Advances the logic sequence one step at a time.

The logic sequence is advanced by channel 7 of the tape reader during an automatic inspection.

Center-Out Logic Sequence (See Figure 3-11):

Sequence

Event Description

0. Inspection start conditions. Tape reader channel 8 increases the recorder current as the inspection surface speed increases resulting from the constant, maximum, 3 rpm turntable speed. The control maintains a constant recording density.



Sequence	Event Description
1.	Indicates that the turntable speed control point is reached. Channel 8 disconnects the recorder current control and decreases the turntable angular velocity.
2.	Indicates that the tangent point has been reached. The search tube axial drive directions are reversed.
3.	Indicates that the upper bulkhead inspection is complete. This logic condition turns off the recorder current, permits the carriages to be stepped to their transfer station, and permits the turntable angular velocity to be returned to a minimum.
4.	This sequence condition turns off the tape reader, starts the outer table to tip, and advances the sequence to sequence 5. Sequence 5 does not commence until sequence 4 is finished.
5.	This sequence starts when 4 is complete. The condition starts the inner table to tip and advances the sequence to 6. Sequence 6 is not allowed to start until 5 is finished.
6.	When sequence 5 is finished, the printer column starts angulating to the intermediate angle point, the printer carriage is stepped downward, and the logic is advanced to sequence 7.
7.	Indicates that the transducer carriages are stepping downward to a lower bulkhead inspection start position. Microswitches terminate the transducer and printer carriage stepping at the 0-0 line reference point.

The tape may now be rewound, changed, and the logic sequence returned to 'home' for an inspection of the lower bulkhead.

CAUTION

The tape reader must be off when the tape is rewound.

NOTE The complete operating sequence described in items 0 through 7 is dependent upon the correct tape program.

Bottom-In Logic Sequence (See Figure 3-11)

Sequence	Event Description
0.	Inspection start conditions. Tape reader channel 8 increases the turntable angular velocity as a result of the inspection of decreasing diameter surface areas. The control maintains a constant inspection surface speed angular velocity.

Sequence	Event Description
1.	Indicates that the inside tangent point has been reached. The inside search tube axial drive direction is reversed.
2.	Indicates that the outside tangent point has been reached. The outside search tube axial drive direction is reversed.
3.	Indicates that the lower bulkhead inspection is complete. This logic condition turns off the recorder current, permits the carriages to be stepped to their transfer stations, and permits the turntable angular velocity to be returned to a minimum.
4.	This sequence condition turns off the tape reader, starts the outer table to tip, and advances the sequence to 5. Sequence 5 does not commence until 4 is finished.
5.	This sequence starts when sequence 4 is complete. The condition starts the inner table to tip and advances the sequence to 6. Sequence 6 is not allowed to start until 5 is finished.
6.	When sequence 5 is finished, the printer column starts angulating to the shallow angle point, the printer carriage is stepped upward, and the logic is advanced to sequence 7.
7.	Indicates that the transducer carriages are stepping upward to an upper bulkhead inspection start position. Microswitches terminate the transducer and printer carriage stepping at the center of the bulkhead.

NOTE: The complete operating sequence described in items 0 through 7 is dependent upon a correct tape program.

Logic Sequence 10: The operator may adjust the recorder current control set point when logic sequence 10 indicates. The Table Speed, Fast-Slow switch varies the recorder current. The switch lights when the CW or CCW potentiometer current limiting resistor rotation limit is reached.

Tape Reader (See Figure 3-13)

Power Supplies power to the tape recorder.

Feed-Forward, Reverse: Disconnected. Feed direction is set by the translator inspection control.

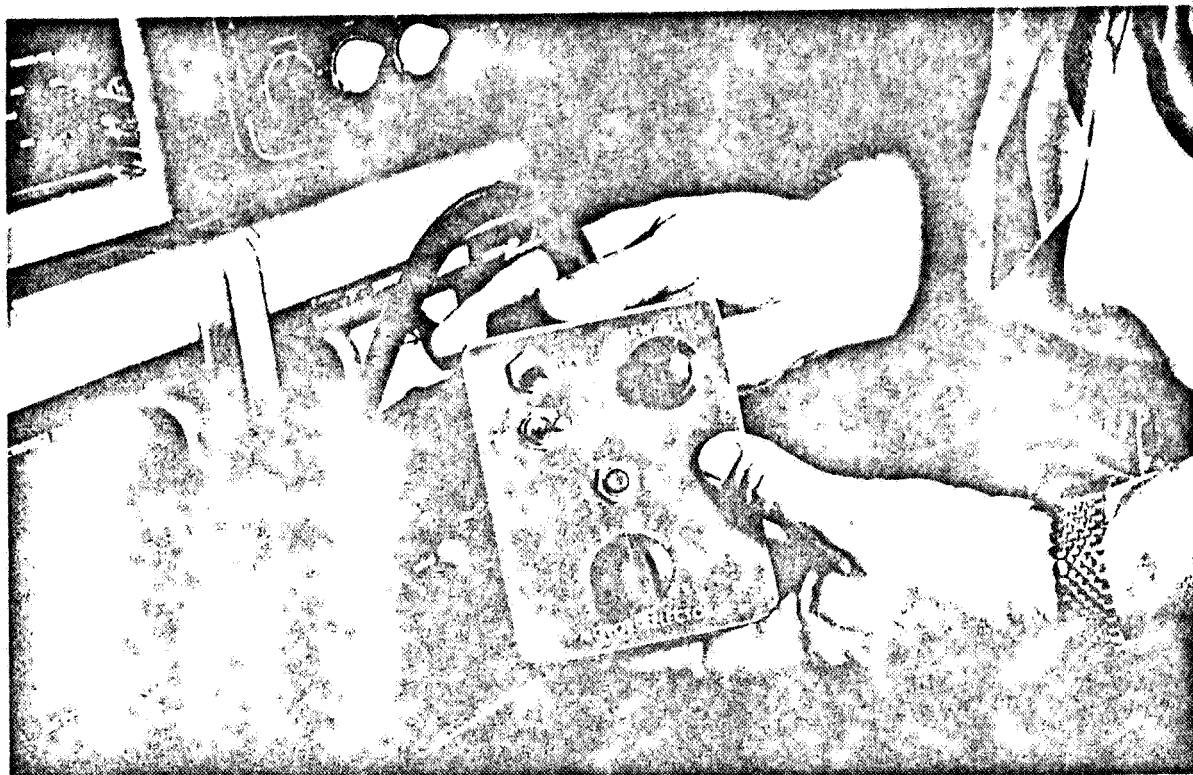


Figure 3-12. Remote Control Pendant

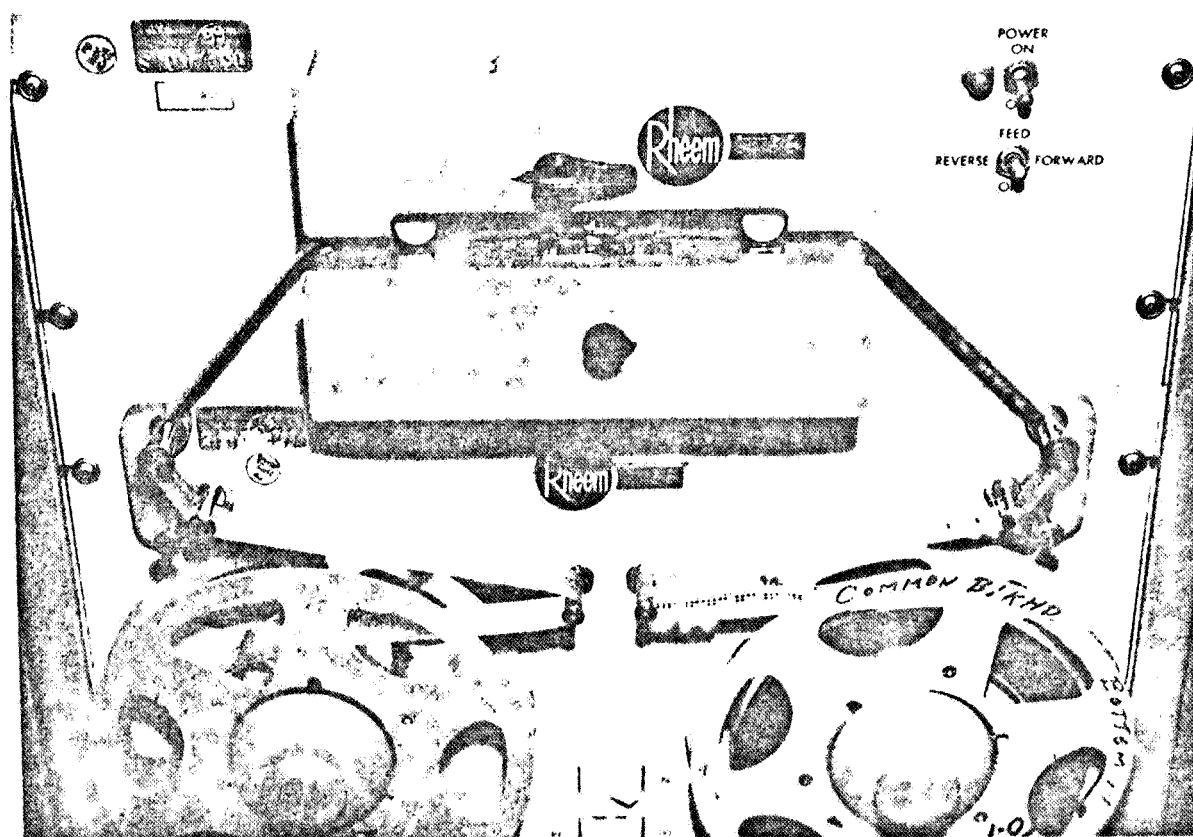


Figure 3-13. Rheem Tape and Controls

Tape Spooler

Power-Off, On: Supplies power to the tape spooler.

Forward-Reverse Controls the tape feed direction for rewinding the tape.

CAUTION

Turn off the Tape Reader before winding the tape.

Instrumentation (See Figures 3-14 through 3-16)

A 424D immerscope, MK-7 flaw detector with gate adapter and an SR-130 recorder adapter are provided for the pulse-echo or through-transmission inspection of the Saturn panels. The standard model 424D, MK-7, and SR-130 instruction manuals are used for each unit.

Gate Adapter (See Figures 3-15 and 3-16)

The gate adapter transforms the MK-7 flaw detector video information into usable gated video information for the SR-130 recorder adapter.

The gate adapter requires a synchronizing pulse and video signal from the MK-7. A bright-up pulse is applied to the MK-7 and intensity modulates the CRT during the gate on time to indicate the relative gate position and duration. Gated video information is applied to the SR-130 recorder adapter.

Panel Description

Power Turns on the gate adapter.

Gate On Turns on the gate generating circuits.

Gate Delay The control is provided to position the gate start with respect to the synchronizing signal.

Gate Width The control adjusts the gate duration with respect to the gate start.

Test Permits the operator to monitor the -150-volt, +150-volt and +300-volt power supplies.

MK-7 - 424D The control switches the transducer input and output and the SR-130 gated video input to the desired sonic unit to permit operation of either sonic unit.

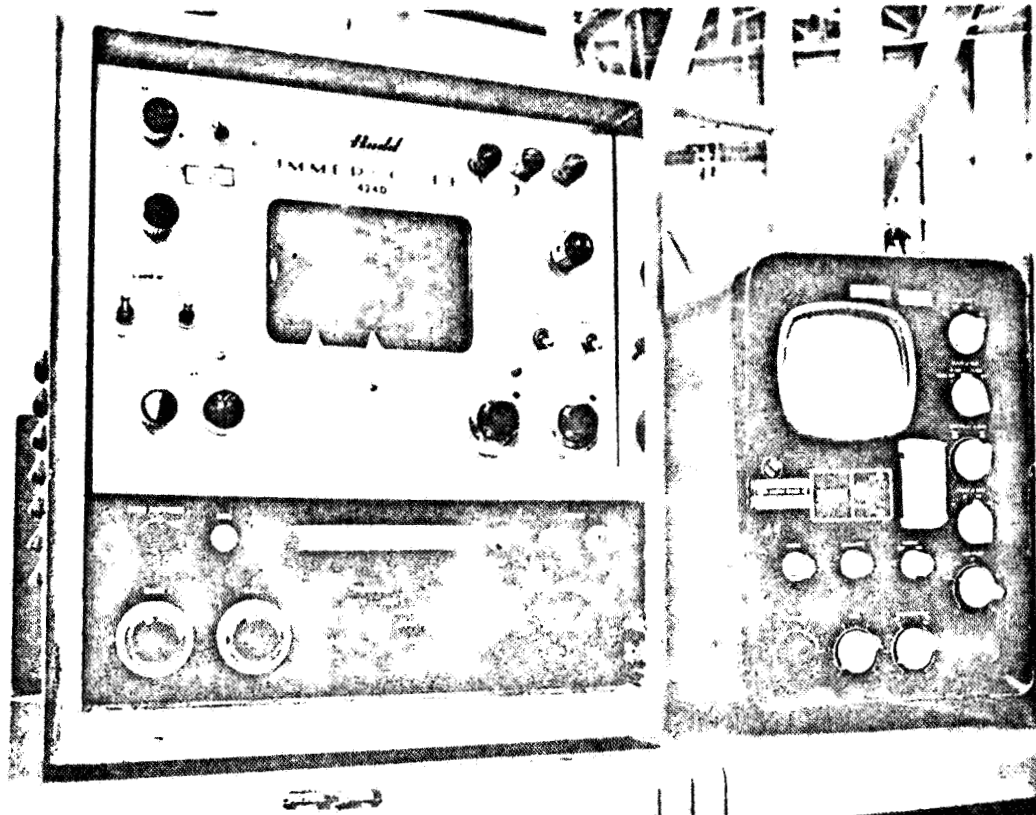


Figure 3-14. Instrumentation (Flaw Detectors)

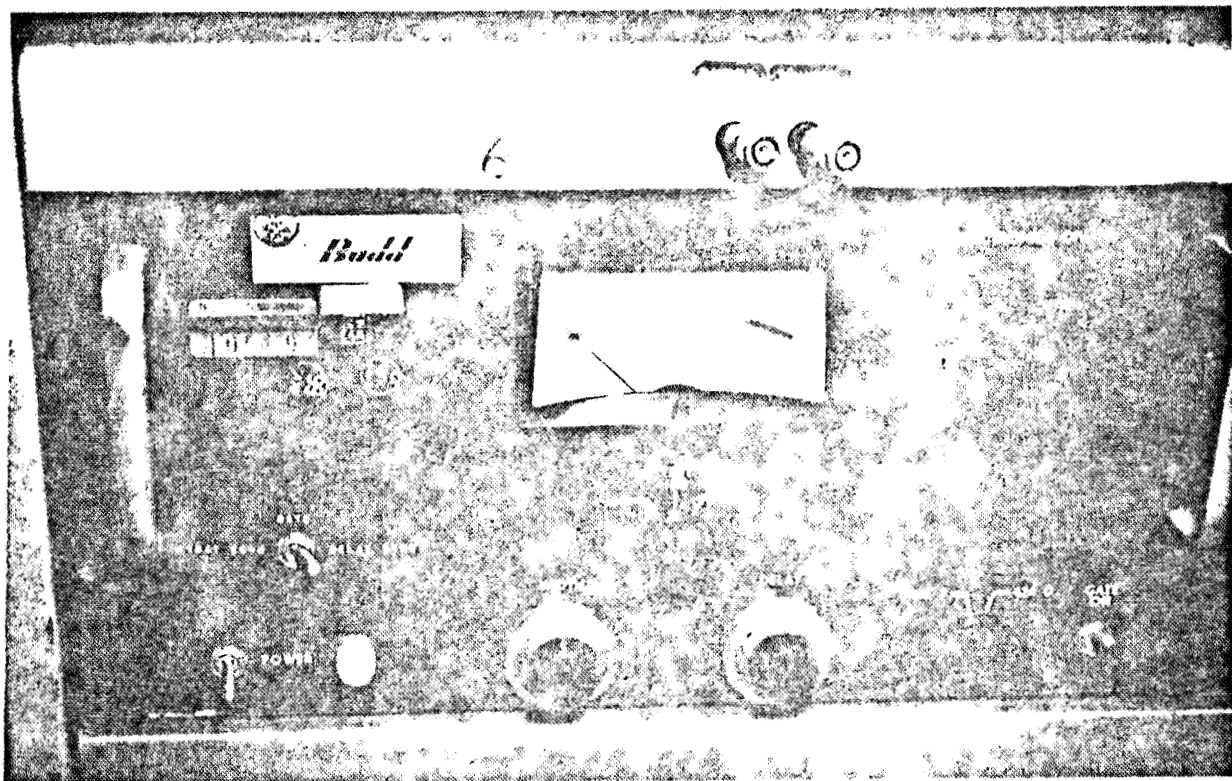


Figure 3-15 Gate Adapter

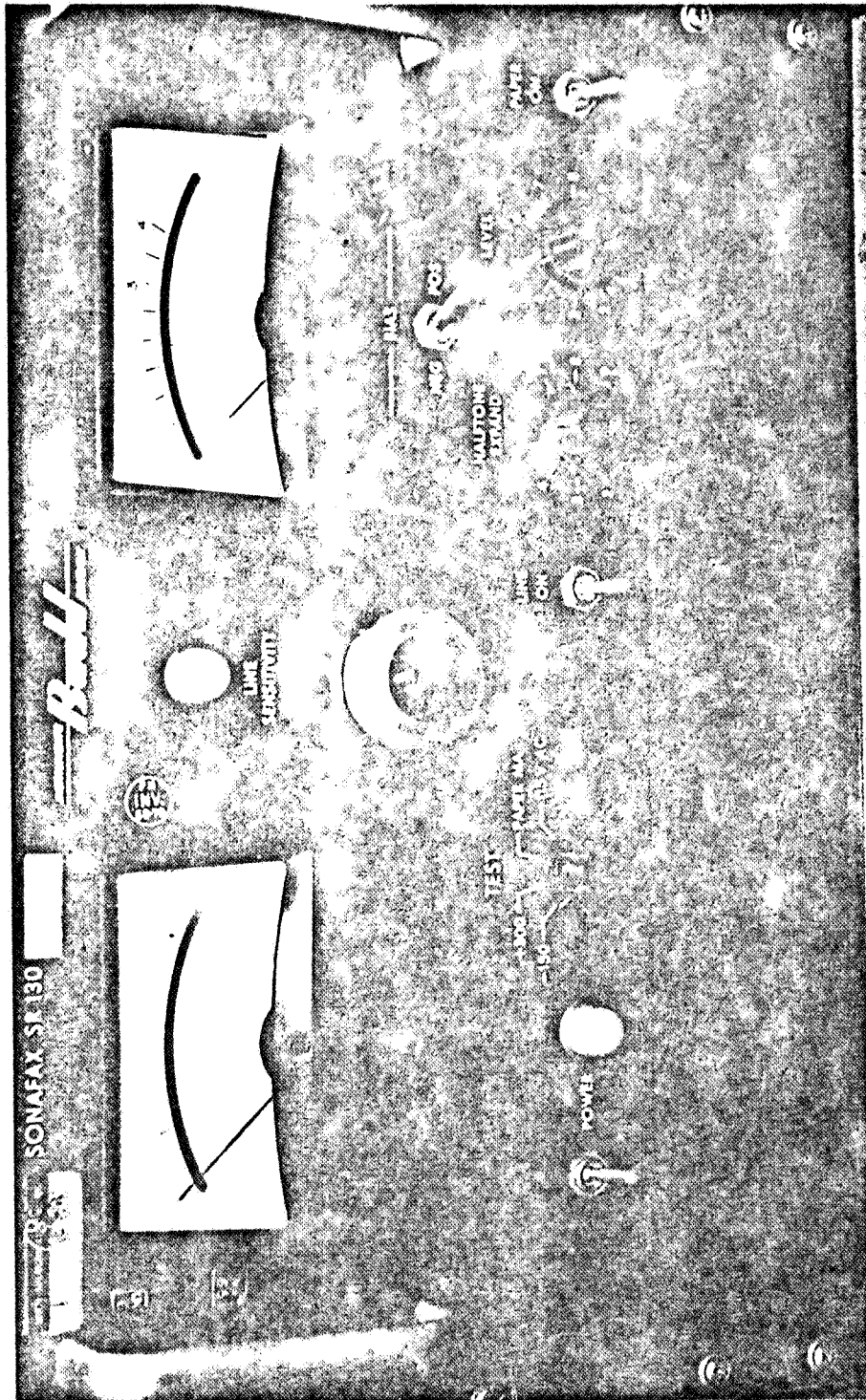


Figure 3-16. Recorder Control Panel



Internal Controls

Video Gain: Adjusts the video signal amplitude to the input of the gated video coincidence tube.

BUP: The bright-up pulse control adjusts the amplitude of the gate pulse applied to the MK-7.

3.1.2 PREINSPECTION PREPARATION

The following preliminary steps are required prior to the start of actual inspection of the common bulkhead on the automated inspection system:

1. **Examine the fabrication and assembly records (FAIR)** associated with the specific bulkhead to be inspected for the history of the internal structure of the sandwich assembly. During the fabrication of the bulkhead assembly, a grid chart (listing all the core splices, core density, internal fittings, thixotropic paste application thicknesses, etc.) is maintained throughout the manufacturing process. After the bulkhead is bonded, the grid chart becomes part of the FAIR records. This information is essential to accomplish the post-inspection evaluation and is used as a reference guide during the inspection process.
2. **Position the outer boom for the bulkhead installation** by rotating to the full extent of travel to the install bulkhead position.
3. **Install the bulkhead** — The bulkhead is installed by skilled material handling crews using the overhead crane to position and align the bulkhead on the tool. A special step-by-step material handling move procedure is utilized for the installation, positioning, and leveling of the bulkhead on the inspection unit turntable.

NOTE: The lower edges of the waffle sections are positioned 10 inches above the surface of the turntable unit.

4. **Position the outer boom back to the bulkhead inspection position.** A manual handcrank at the base of the support column assists in locating the boom in place. Assure positive positioning of this outer boom prior to moving any of the carriages.



5. Position and attach the reference test standard to the mechanically driven turntable assembly.
6. Adjust the instrumentation to the standard to achieve an optimum signal for the parameters defined in NR SD Quality Control Specification MQ0501-010, (Inspection, Ultrasonic).

3.1.3 INSPECTION PROCEDURE

This section outlines the step-by-step sequence used to inspect a completed common bulkhead for bonding integrity. It is essential that operators become thoroughly familiar with the system and the functions of all controls prior to performing the inspection of a bulkhead assembly. Damage to the bulkhead can result through erroneous operation of the system. The step-by-step sequence follows:

1. Activate the main panel switch and console control panel switch. These switches apply power (115 vac) to the translator arm, tape reader, tape spooler, SR-130 recorder adapter, and sola regulators. Allow approximately 30 minutes as a warmup period for instrumentation system prior to use.
2. Energize the water pump and adjust the regulators to obtain an acceptable laminar flow pattern of water couplant from the collimators or nozzles (squirter heads).
3. Set selector switch to "bulkhead" position. Manually adjust outer and inner carriage assemblies to position the nozzles so that the flow of couplant is directed at the apex of the bulkhead. The rotational axis of the nozzles must be approximately 9 inches from the surface of bulkhead facesheets being examined.
4. Manually normalize the inner nozzle to obtain maximum response (pulse-echo)
5. Manually position the outer nozzle to achieve maximum response (through-transmission)

NOTE: Ultrasonic system instrumentation parameters shall be comparable to the settings established through the use of the reference standard (i.e., gain frequency, transducers, and gate adjustments), and are as defined in NR/SD Quality Control Specification MQ0501-010.

6. Position Tape No 1 and center out the tape spooler.

7. Set logic sequence to the "home" position.
8. Set inspection switch to the "center-out" position.
9. Set Printer to the "normal" position. Establish the turntable speed at approximately 3 revolutions per minute or 18 inches of travel per second. Cover the recording model or drum with tracing paper using extreme care to prevent wrinkles.
10. Set the recording arm at the apex of the drum and adjust the stylus to assure proper tension

NOTE: Align the television camera to observe the proper tracking of the inner nozzle.

11. Push the automatic start button and adjust the speed and index controls to achieve approximately 0.060 inch of index travel per turntable revolution. Monitor the oscilloscope to compare scope indications with the recording indications continually during the inspection. Continue the inspection operations until the carriages reach the transfer table change-over position
12. Verify all the through-transmission "void" indications recorded on the tracing (Figure 3-17). Compare these void indications with the grid chart previously made of the internal sandwich structure. These suspect areas are then correlated to specific locations on the bulkhead. A supplementary pulse-echo inspection (reference NR/SD Quality Control Specification MQ0501-010) is performed on both surfaces for all through-transmission "no-signal" indications on the recording

NOTE: Verify proper change-over of the transfer tables prior to proceeding

13. Position the inner nozzle to a distance measuring 30.5 inches from the turntable and normalized for maximum response (pulse-echo).
14. Position the outer nozzle for maximum response (through-transmission)
15. Replace Tape No. 1 with Tape No. 2 and bottom-in the tape spooler and count 45 speed holes. Inspection of the lower section of the bulkhead will start at this point

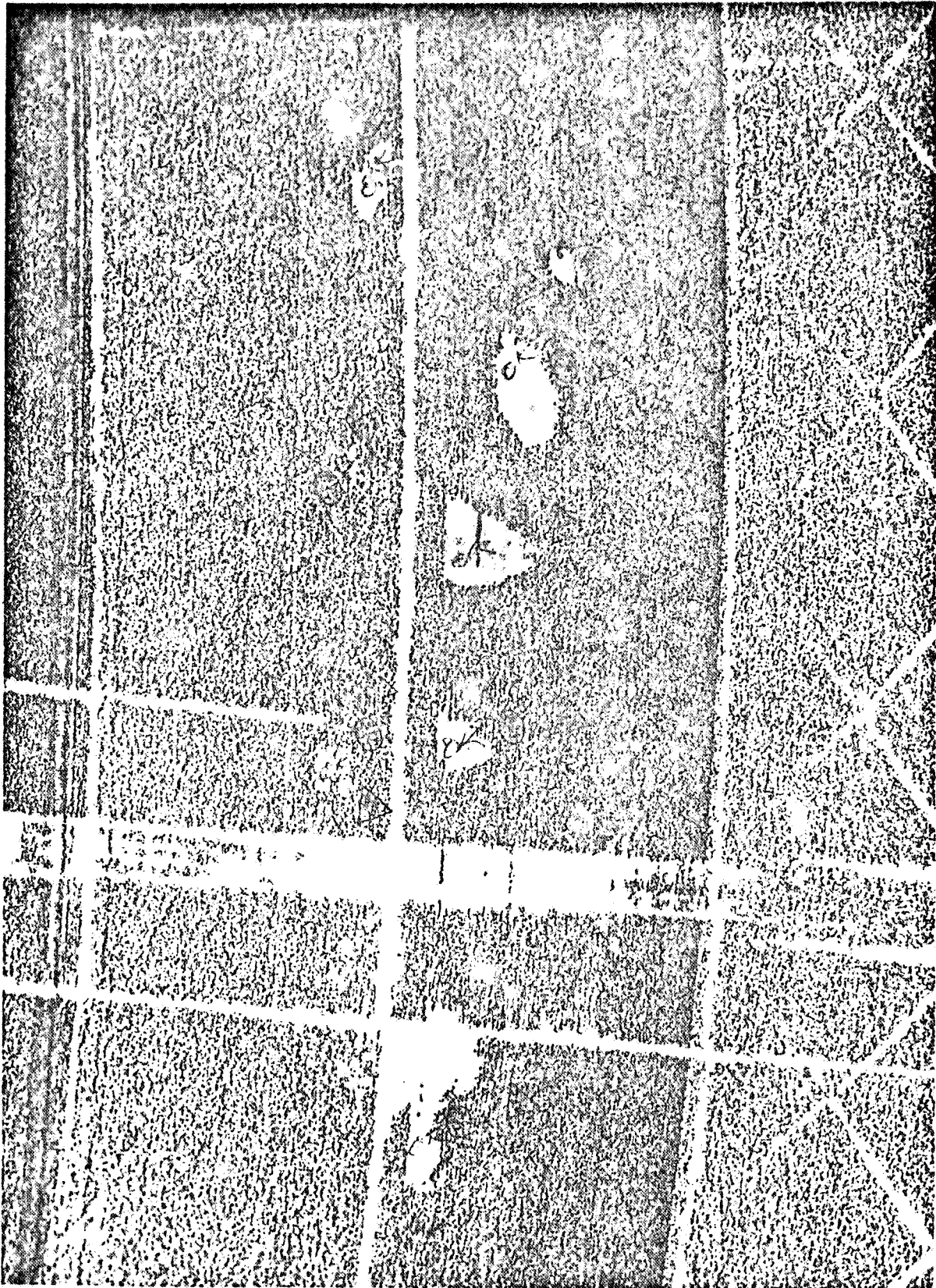


Figure 3-17. Recording of Inspection, "C" Scan

16. Reset all control settings to obtain ultrasonic system instrumentation parameters that are comparable to those established by using the reference standard and defined in NR/SD Quality Control Specification MQ0501-010.
17. Reset all control switches for "bottom-in" sequence.
18. Push the automatic-start button and continue inspection operations until at least 3 inches of overlap to the inspection recording for the upper section of the bulkhead is achieved.
19. Verify all the through-transmission "void" indications recorded on the tracing. Compare these void indications with the grid chart previously made of the internal sandwich structure. These suspect areas are then correlated to specific locations on the bulkhead. A supplementary pulse-echo inspection (reference NR/SD Quality Control Specification MQ0501-010) is performed on both surfaces for all through-transmission "no-signal" indications on the recording.

NOTE: Verify proper change-over of the transfer tables prior to proceeding.

20. Position the outer nozzle to a distance measuring 30 5 inches from the top of the turntable and normalized for the maximum pulse-echo response.
21. Using Tape No. 2 "bottom-in", count 45 speed holes, and energize the tape reader at this point.
22. Set the logic sequence to the "home" position.
23. Set the inspection mode to the "bottom-in" position.
24. Set the printer mode to the "outer" column.
25. Attach the pulse-echo test standard on the bulkhead and adjust to the parameters defined in NR/SD Quality Control Specification MQ0501-010 and related manufacturing specifications.
26. Reset the inspection mode switch to "bottom-in" reverse and position the track tape using manual mode to 1/4-inch below the horizontal weld land.



27. Reset the inspection mode switch to "bottom-in forward." The pulse-echo inspection of the outboard surface will start at this point and will extend up 15 inches.
28. Adjust the turntable speed to 1.5 rpm and set the motor control switch to "auto/with tape."
29. Push the automatic start-stop button and continue inspection operation until completion of the inspection and the recording of the lower 15-inch area.
30. Compare all void indications recorded on this tracing with the grid chart previously made of the internal sandwich structure and the tracing recorded for the through transmission inspection.

NOTE: The pulse-echo inspection (21-31) is accomplished on the lower 15 inches only to supplement the through-transmission inspection. Experience has revealed that small singular-type voids could be completely engulfed by sound waves in this reduced core thickness area when using the through-transmission method. The supplemental pulse-echo inspection of this area will reveal these small singular voids.

3.1.4 POST-INSPECTION PROCEDURE

A final evaluation of all the ultrasonic inspection indications is required to analyze and assess the bonding integrity of the common bulkhead assembly. In this final evaluation, all documented history of the internal structure that was recorded on the grid chart (see section 3.1.2) is correlated to the through-transmission and pulse-echo inspection results. The following sequence is used to establish a summary of the inspection results:

1. Compare the signal-attenuated areas on the recording (light areas) of the through-transmission inspection with the identical areas on the grid chart.
2. Evaluate and note the results of the pulse-echo inspections for all the signal-loss areas of the through-transmission inspection as indicated on the recording.



3. Perform radiographic inspection, if required, to detect the presence (or absence) of cocked or canted core when the evaluation indicates this to be a possible cause of the through-transmission signal attenuation.
4. Evaluate suspect areas by using sonic methods when this method can be used as a supplement to help establish or facilitate the exact location of void indications
5. Submit all out-of-tolerance debond indications to Material Review for disposition. Detailed locations, together with the surface location of the debond, will be included in the information submitted to the Material Review Board.

3.2 AFT LO₂ BULKHEAD DOLLAR WELD INSPECTION

The aft LO₂ bulkhead dollar section is joined to the bulkhead by butt welds made from opposite sides with overlapping nuggets. Because of the weld method, this weld receives a supplemental ultrasonic inspection using the shear wave contact method. This additional inspection method is performed specifically for lack of complete joint penetration of the weld passes.

The normal operating procedure of the Krautkramer is not discussed because it is assumed that the operator will have a basic understanding of ultrasonics and will use the standard operating manual published for this unit. Although the Krautkramer is a diversified instrument, the procedure discussed will be limited to the essentials necessary to inspect for incomplete penetration between the two weld passes made from opposite sides of the assembly

Procedure

Special Equipment and Materials Required

1. Krautkramer USIP10 flaw detector (see Figure 3-18)
2. One 70-degree, 4-MHz shear-wave transducer (large probe)
3. One 70-degree, 4-MHz shear-wave transducer (miniature probe)
4. One 6-inch scale
5. One shear-wave calibration block
6. One standard (standard contains known discontinuities typical of flaws to be encountered)
7. Couplant - petroleum jelly

NOTE: The inspection is normally accomplished from the outboard surface (non-LO₂ wetted) only
If inspected from the inboard surface, LO₂ compatible couplant would be required (KEL-F)

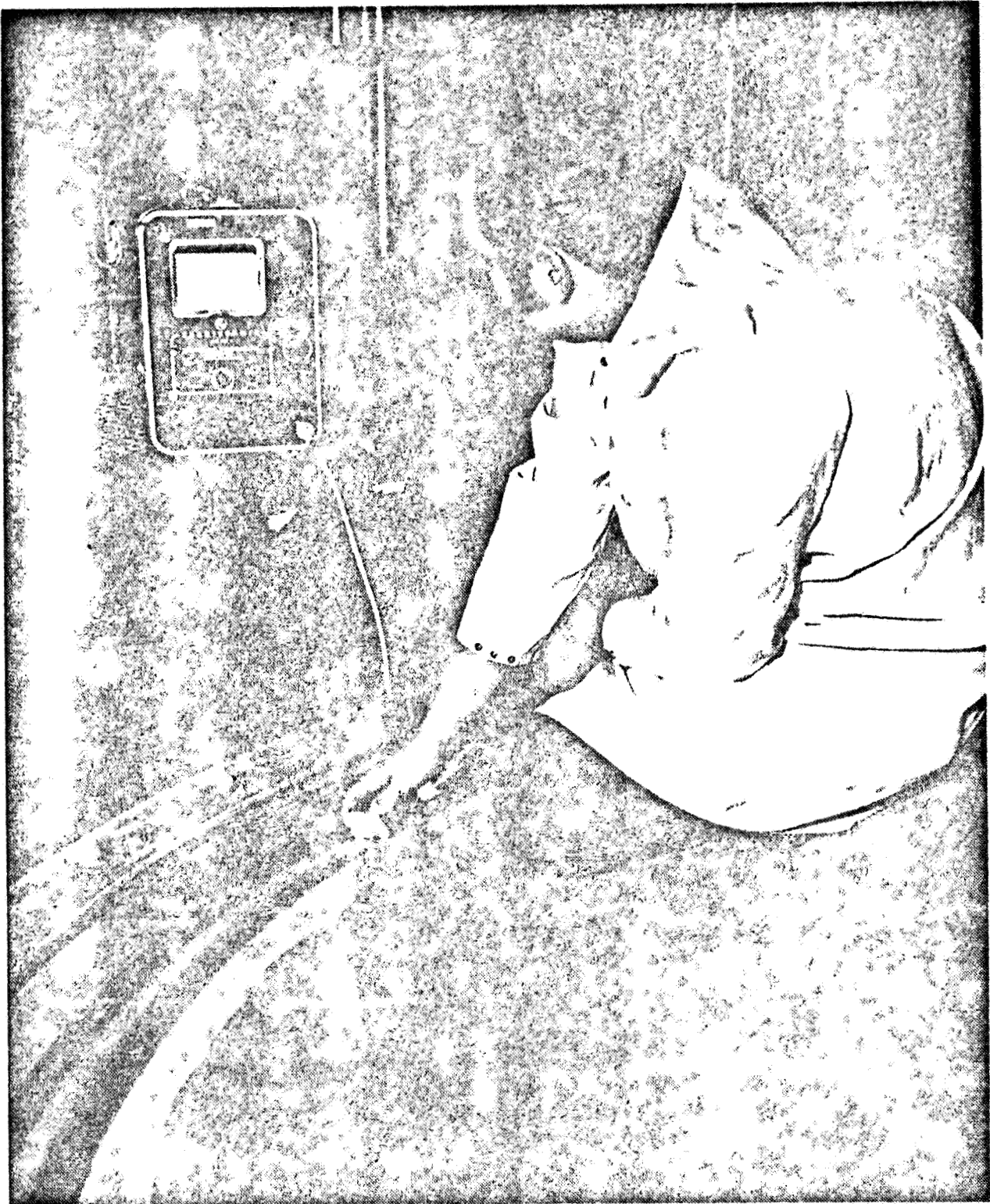


Figure 3-18. Shear Wave Inspection of Dollar Weld

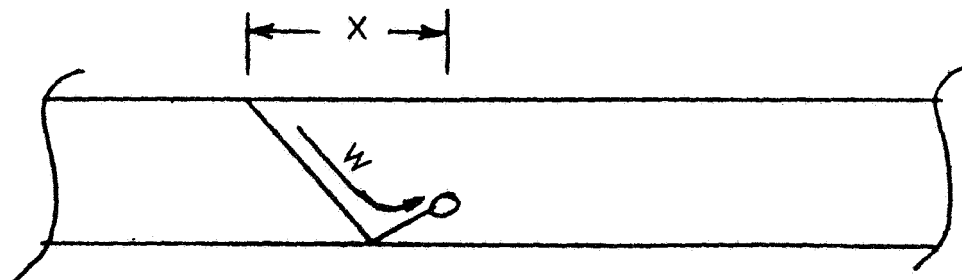


Preparation

1. Warm up unit at least 15 minutes in accordance with the operating manual.
2. Calibrate the instrument on the ultrasonic detector 0 to 5-inch scale for beam travel using the shear-wave calibration block made of the same material as that to be inspected.

Inspection

1. Using the 2-inch regular size shear-wave transducer, scan the weld in a back and forth motion transverse to the weld.
2. Using this back and forth motion and moving at a rate of one-half the probe diameter for each successive unscanned area, continue around the circumference until the entire weld has been inspected.
3. Mark all flaw indications on the assembly.
4. When flaws are detected, the indications will be directly related to similar known conditions on the test standard for confirmation of the suspect discontinuity.
5. When flaws are confirmed with the large transducer, the transducer is replaced with a miniature shear-wave probe. Recalibration is required.
6. Using the miniature probe, evaluate the flaw indications for size, depth, and location within the weld. This can be simplified by using the following formula to facilitate determination of the exact location:



$$X = W (\sin 70^\circ)$$
$$\sin 70^\circ = 0.9397$$

7. All flaw indications detected during this inspection will be correlated with indications on the radiographs of the weld to facilitate interpretation of the internal discontinuities